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(12) **United States Patent**
Saitoh et al.

(10) **Patent No.: US 11,945,034 B2**
(45) **Date of Patent: Apr. 2, 2024**

(54) **CUTTING INSERT AND CUTTING EDGE REPLACEMENT TYPE CUTTING TOOL**

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(72) Inventors: **Hiroto Saitoh**, Narita (JP); **Syoujirou Touma**, Narita (JP)

(73) Assignee: **MOLDINO TOOL ENGINEERING, LTD.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 596 days.

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(86) PCT No.: **PCT/JP2019/016814**
§ 371 (c)(1),
(2) Date: **Dec. 4, 2020**

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PCT Pub. Date: **Dec. 12, 2019**

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(30) **Foreign Application Priority Data**
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(51) **Int. Cl.**
B23C 5/16 (2006.01)
B23B 27/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B23B 27/22*** (2013.01); ***B23C 5/1027*** (2013.01); ***B23C 5/202*** (2013.01); *B23C 2240/24* (2013.01)

(58) **Field of Classification Search**
CPC B23B 27/22; B23B 27/141; B23B 2200/0409; B23C 5/202;
(Continued)

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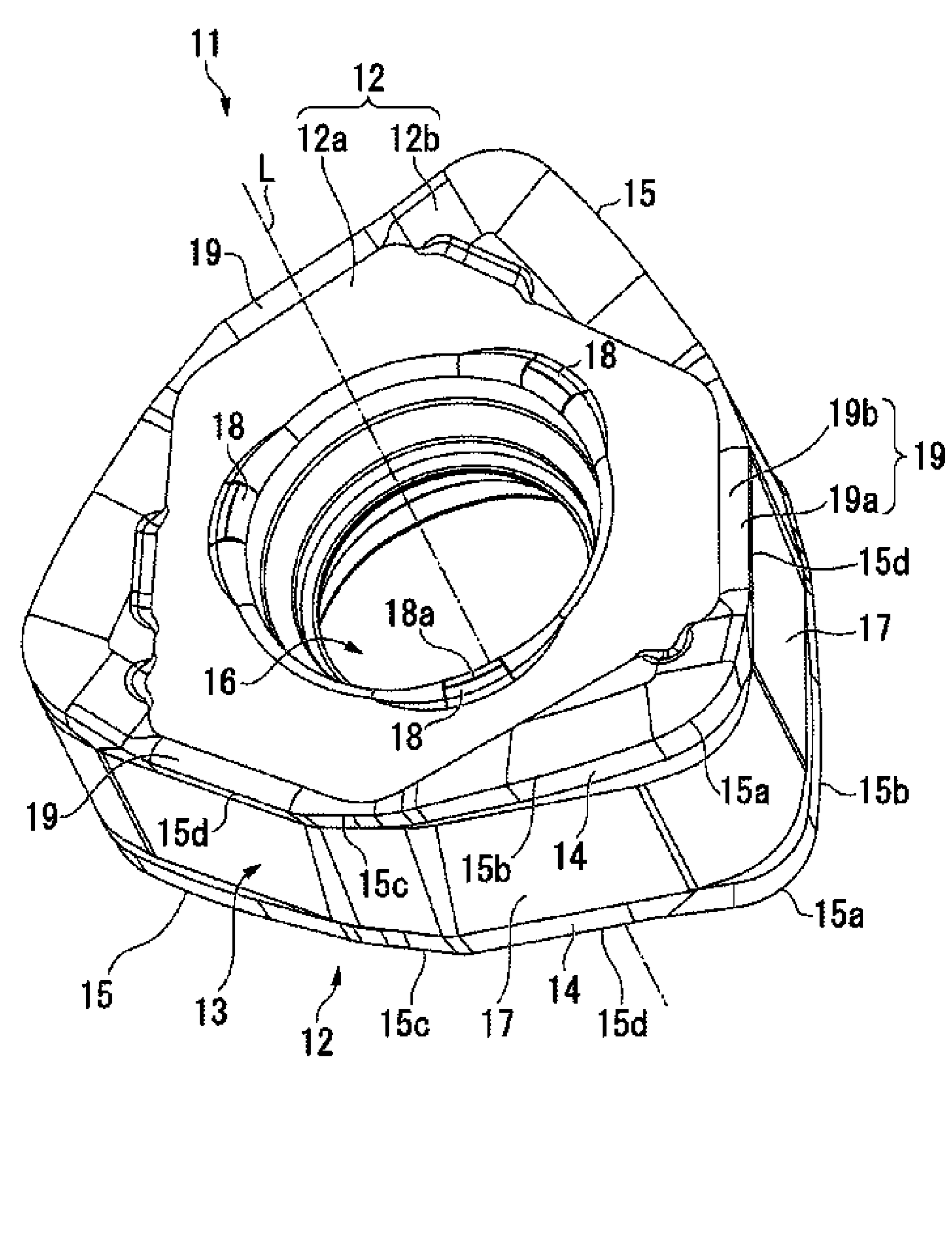
Primary Examiner — Sara Addisu
(74) *Attorney, Agent, or Firm* — Locke Lord LLP

(57) **ABSTRACT**

What is presented is a cutting insert including a polygonal plate-shaped insert main body that includes: two polygonal surfaces; a side surface; and a cutting edge, the insert main body has a mounting hole that is centered on an insert center line passing through centers of the two polygonal surfaces, the cutting edge includes a major cutting edge extending from a first end of a corner edge located at a corner of the polygonal surface, and, in the opening of the mounting hole, a plurality of protrusions protruding with respect to a boss surface around an opening of the mounting hole are formed at intervals in a peripheral direction in an inner periphery side region of the major cutting edge.

12 Claims, 27 Drawing Sheets



(51) **Int. Cl.**
B23C 5/10 (2006.01)
B23C 5/20 (2006.01)
B23C 5/22 (2006.01)

(58) **Field of Classification Search**
CPC B23C 2200/0411; B23C 2200/081; B23C 2200/323; B23C 5/205; B23C 2200/369; B23C 5/1027; B23C 2240/24; B23C 5/06; B23C 2200/361
See application file for complete search history.

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Notice of Allowance dated Jul. 11, 2023, issued for CN201980037682.4 and English translation of the Search Report.

* cited by examiner

FIG. 1

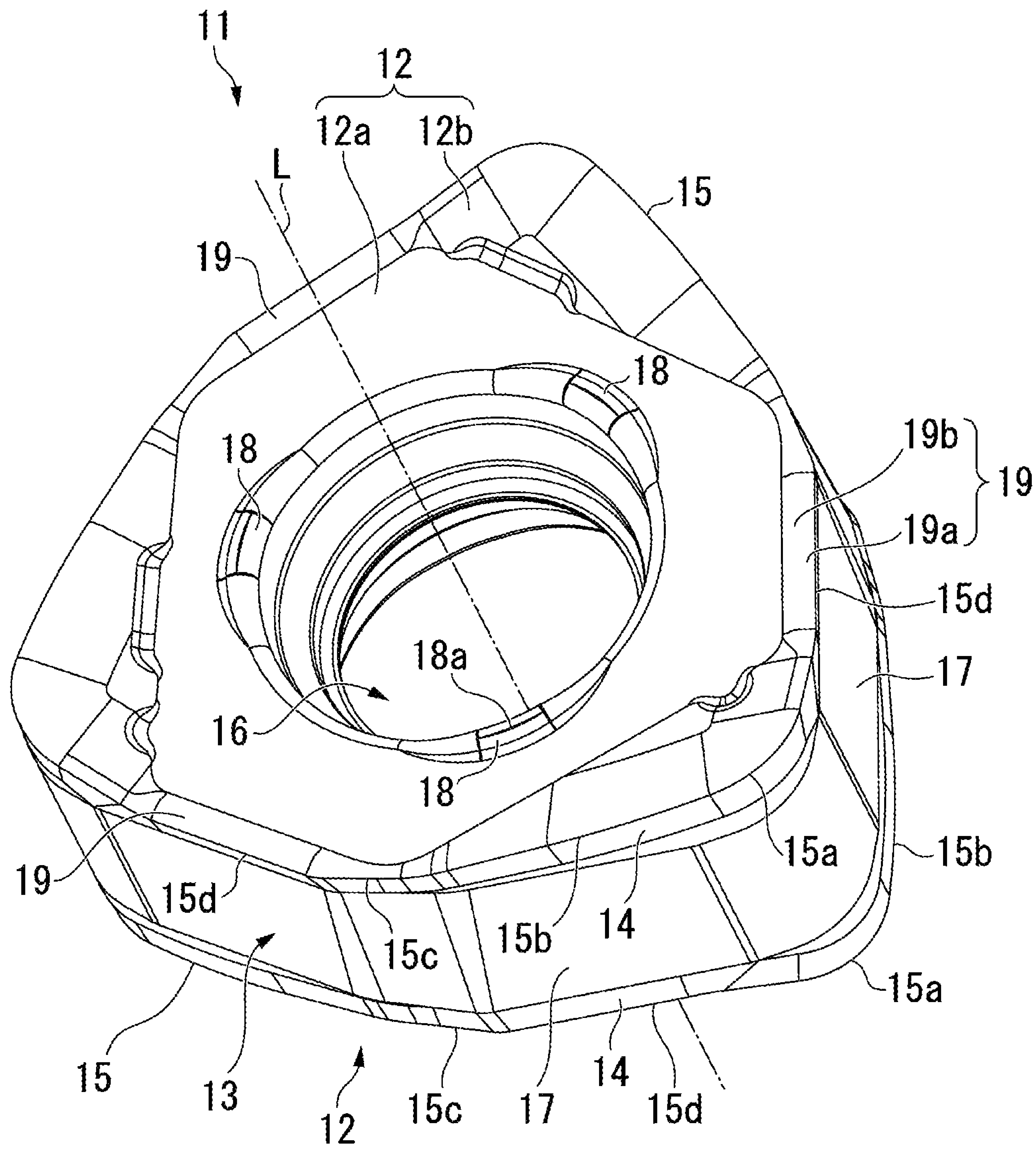

11
12
12a
12b
L
15
19
18
18
19b
19
19a
15d
17
18a
16
18
15a
15b
19
15d
15c
15b
14
15a
15
13
12
15c
17
14
15d

FIG. 2

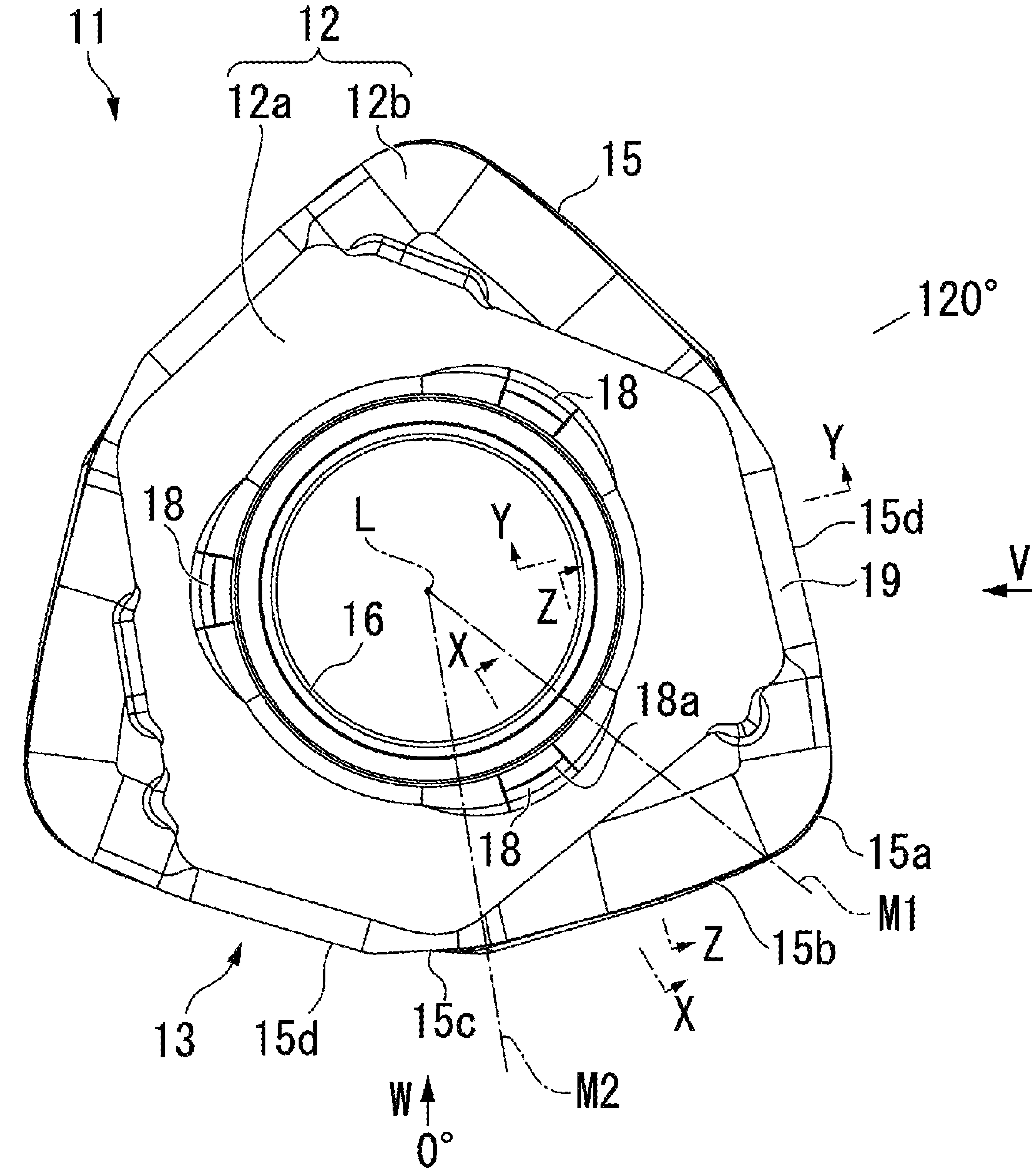

11
12
12a
12b
15
120°
18
Y
15d
L
Y
V
18
19
Z
16
X
18a
18
15a
M1
Z
15b
X
13
15d
15c
M2
W
0°

FIG. 3

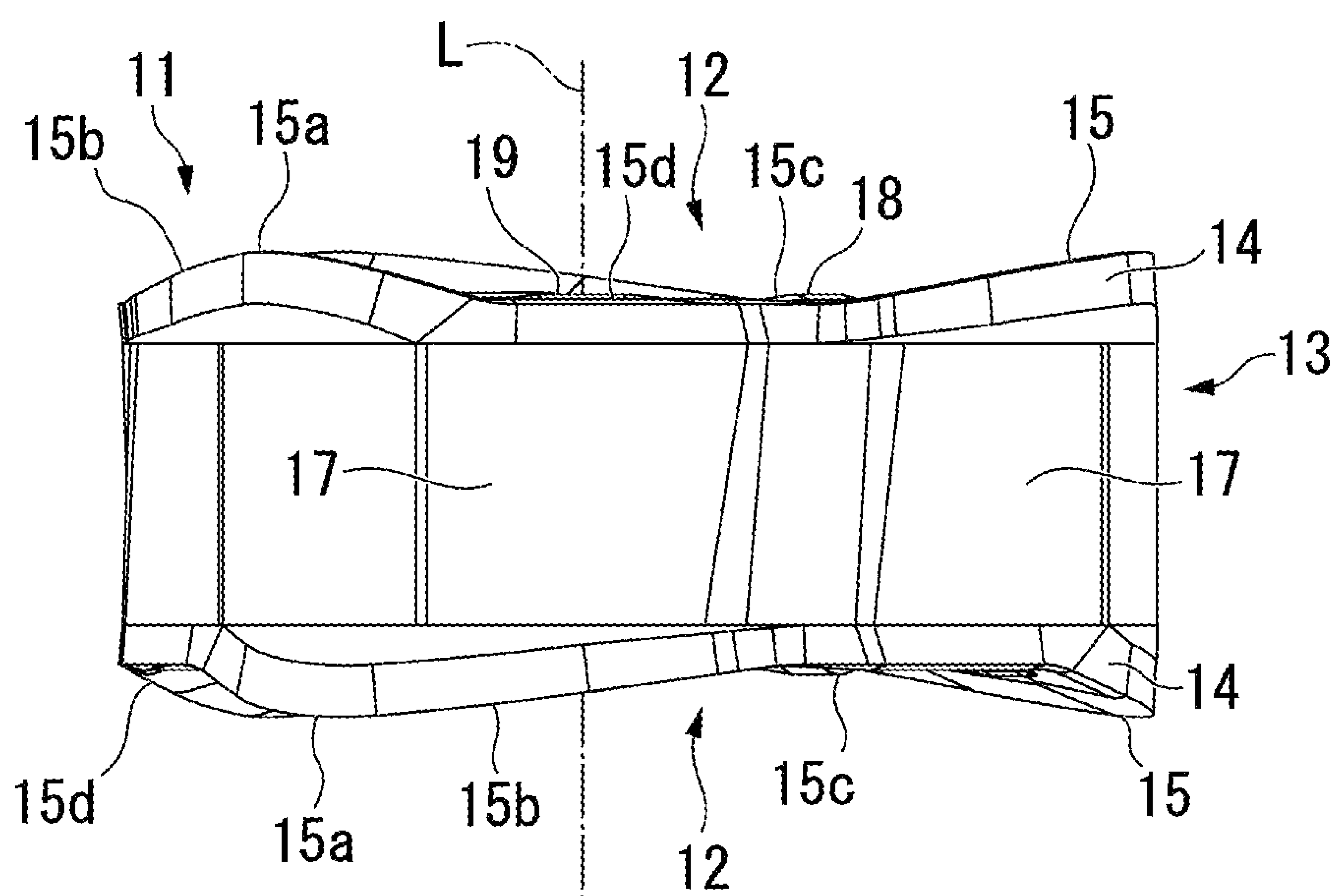

L
11
12
15b
15a
19
15d
15c
18
15
14
13
17
17
14
15d
15a
15b
12
15c
15
12

FIG. 4

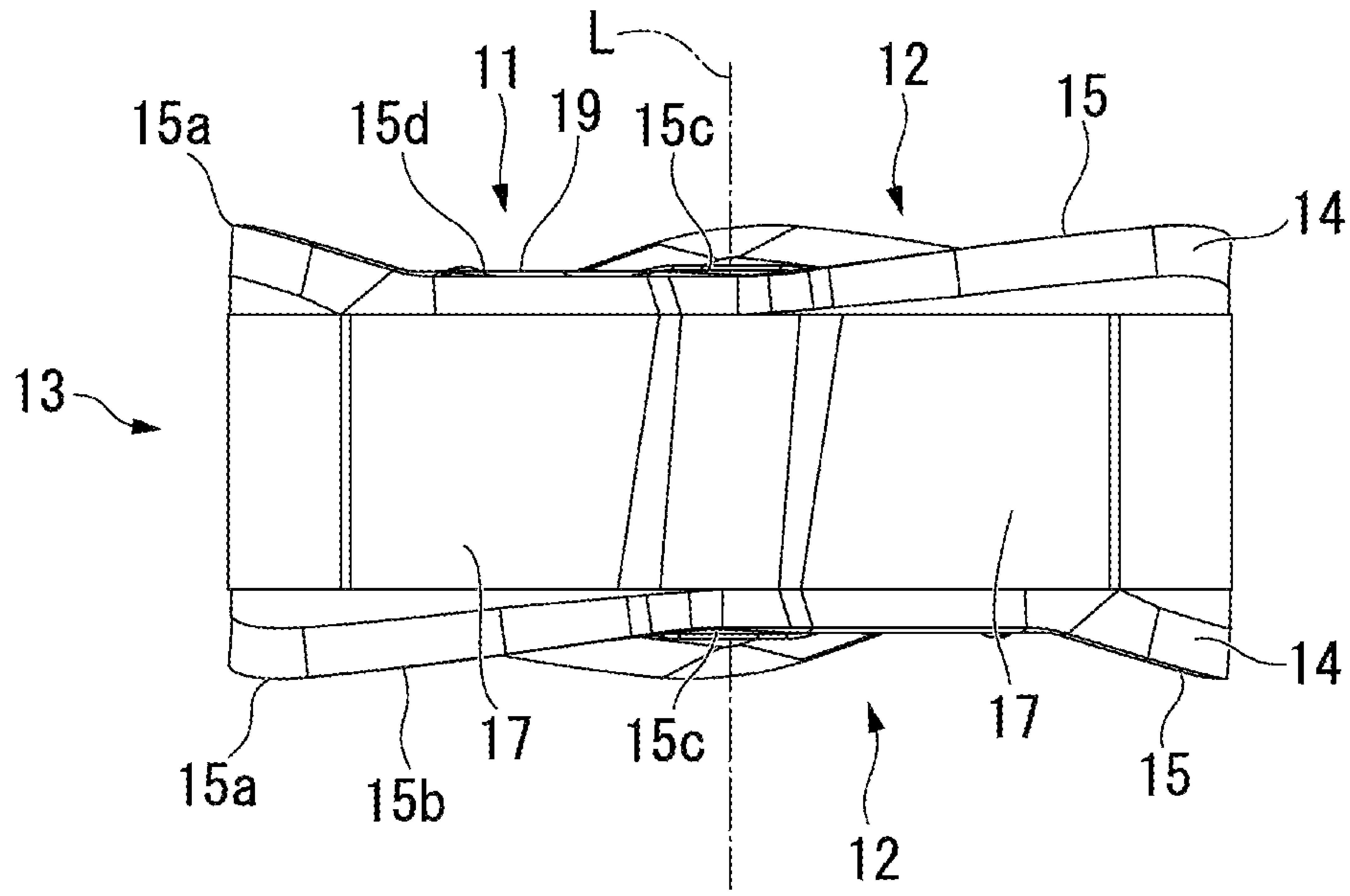

L
11
12
15
15a
15d
19
15c
14
13
17
17
14
15a
15b
15c
12
15

FIG. 5

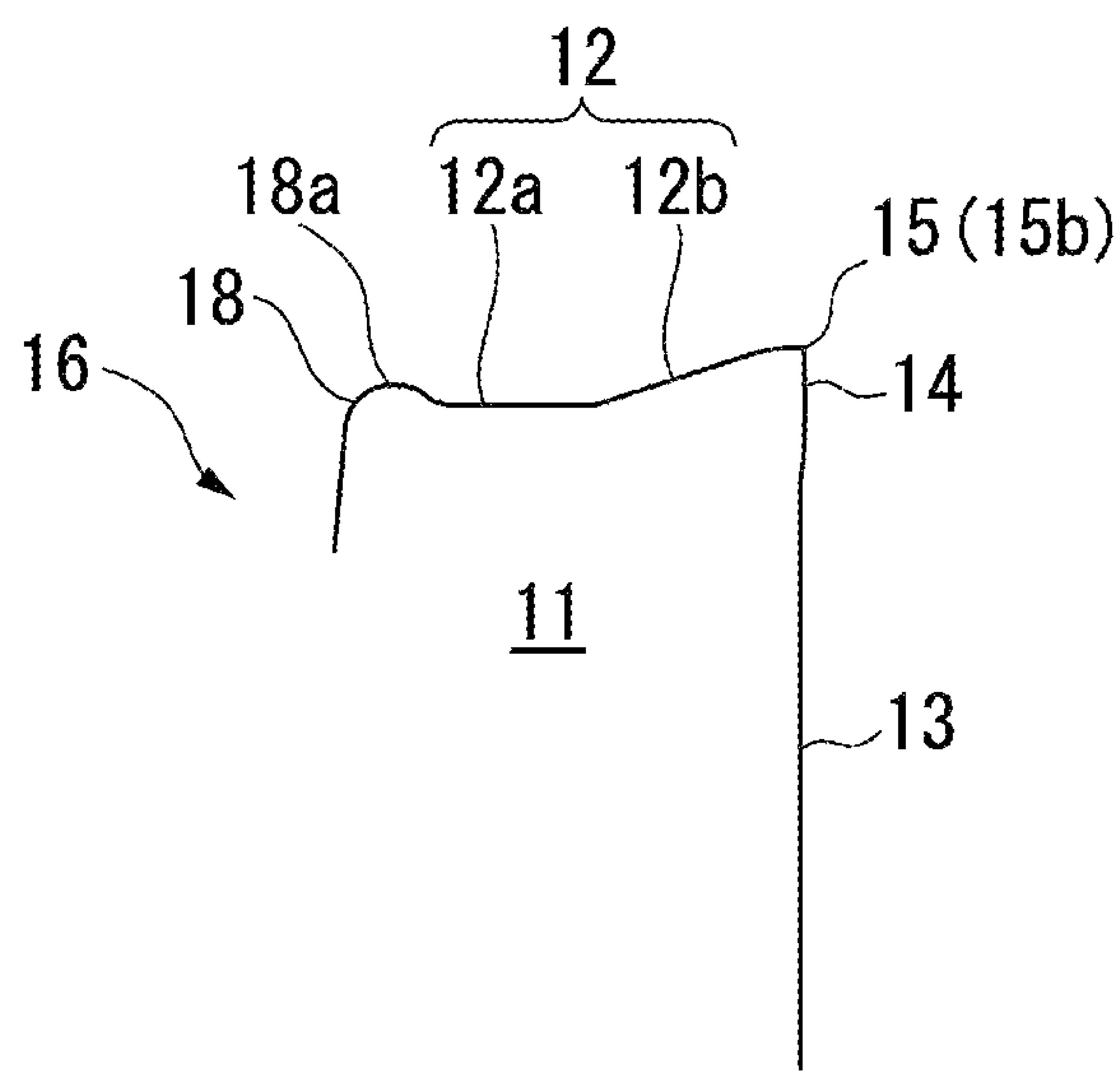

12
18a
12a
12b
15 (15b)
18
16
14
11
13

FIG. 6

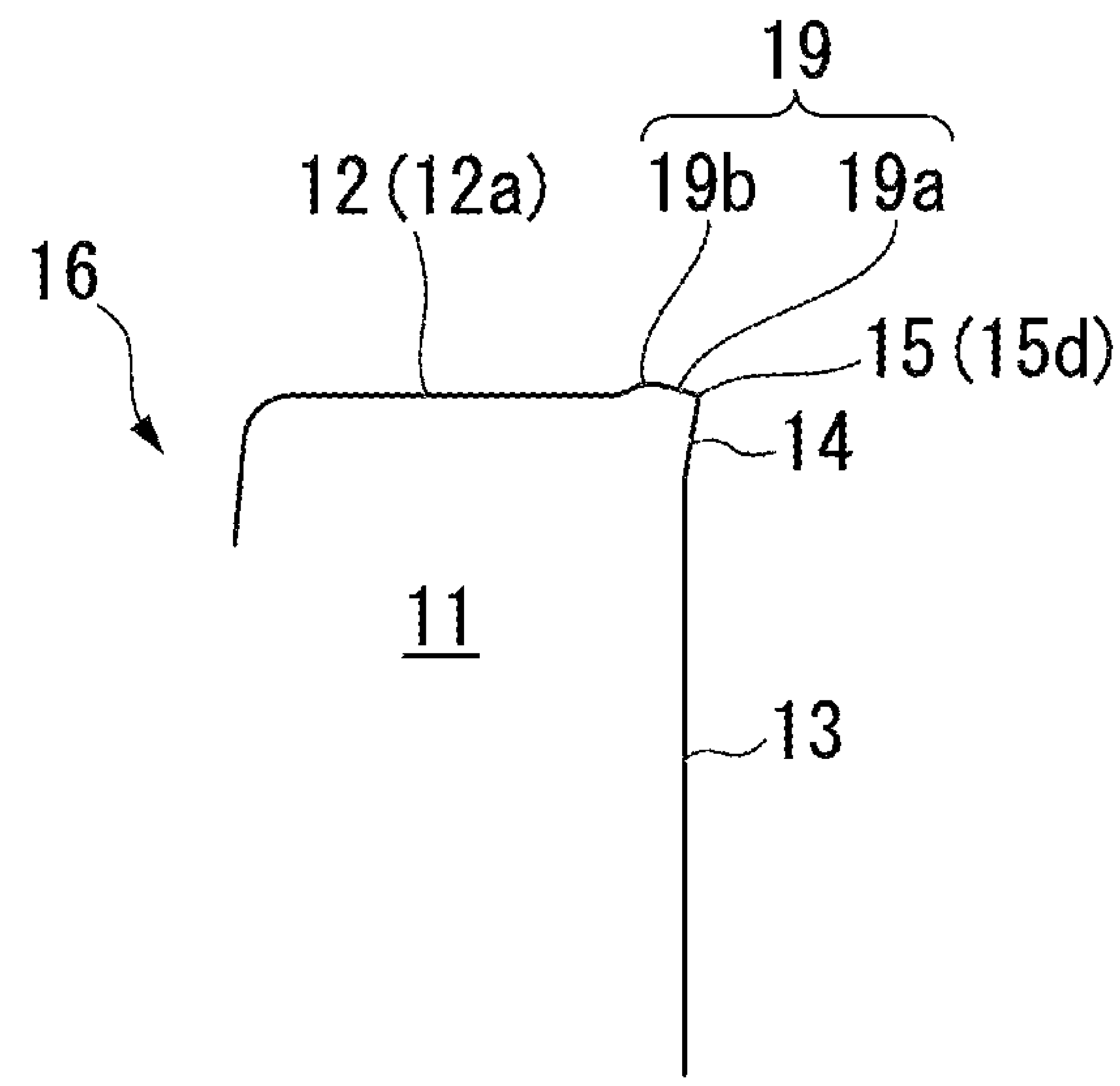


FIG. 7

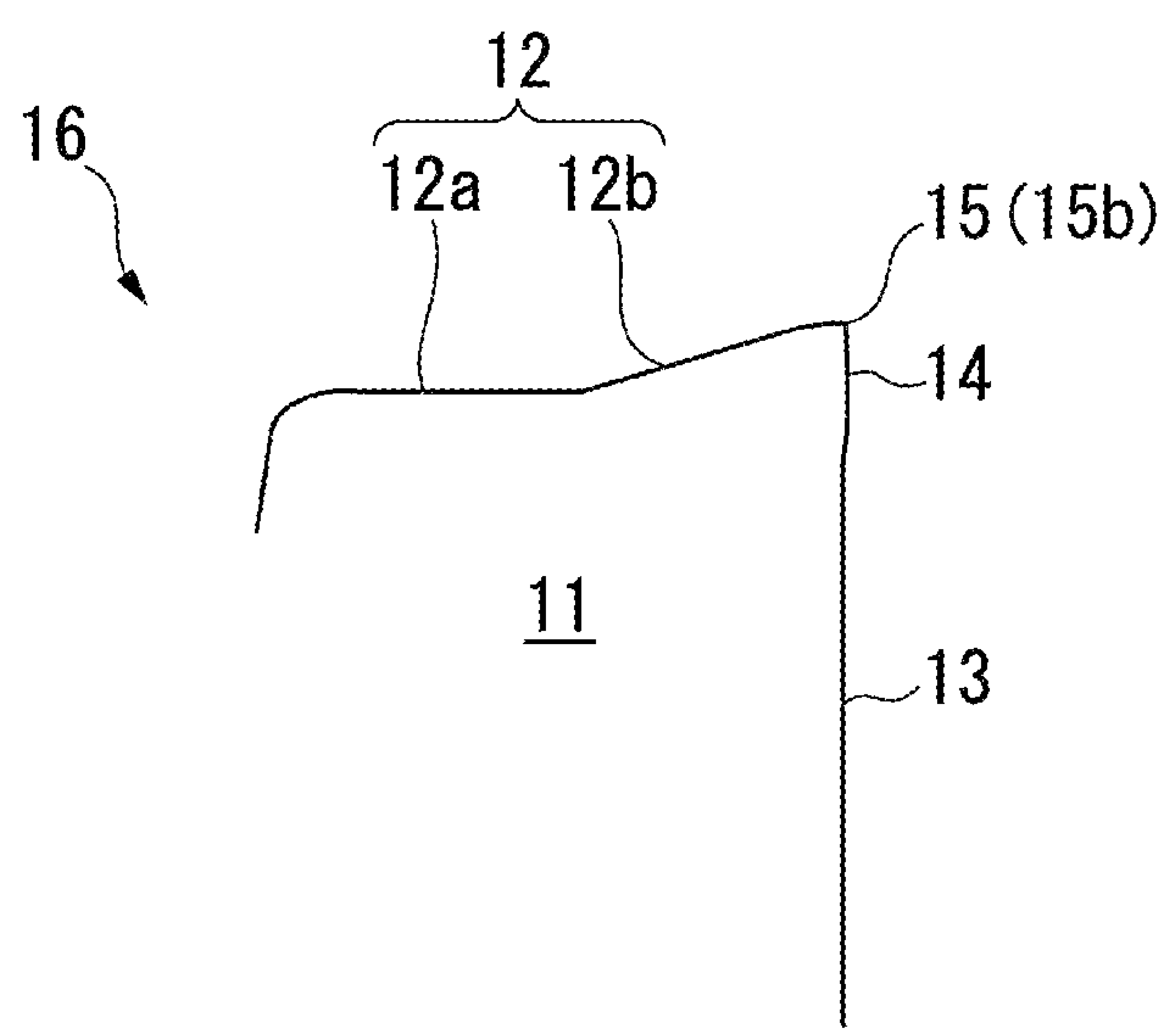


FIG. 8

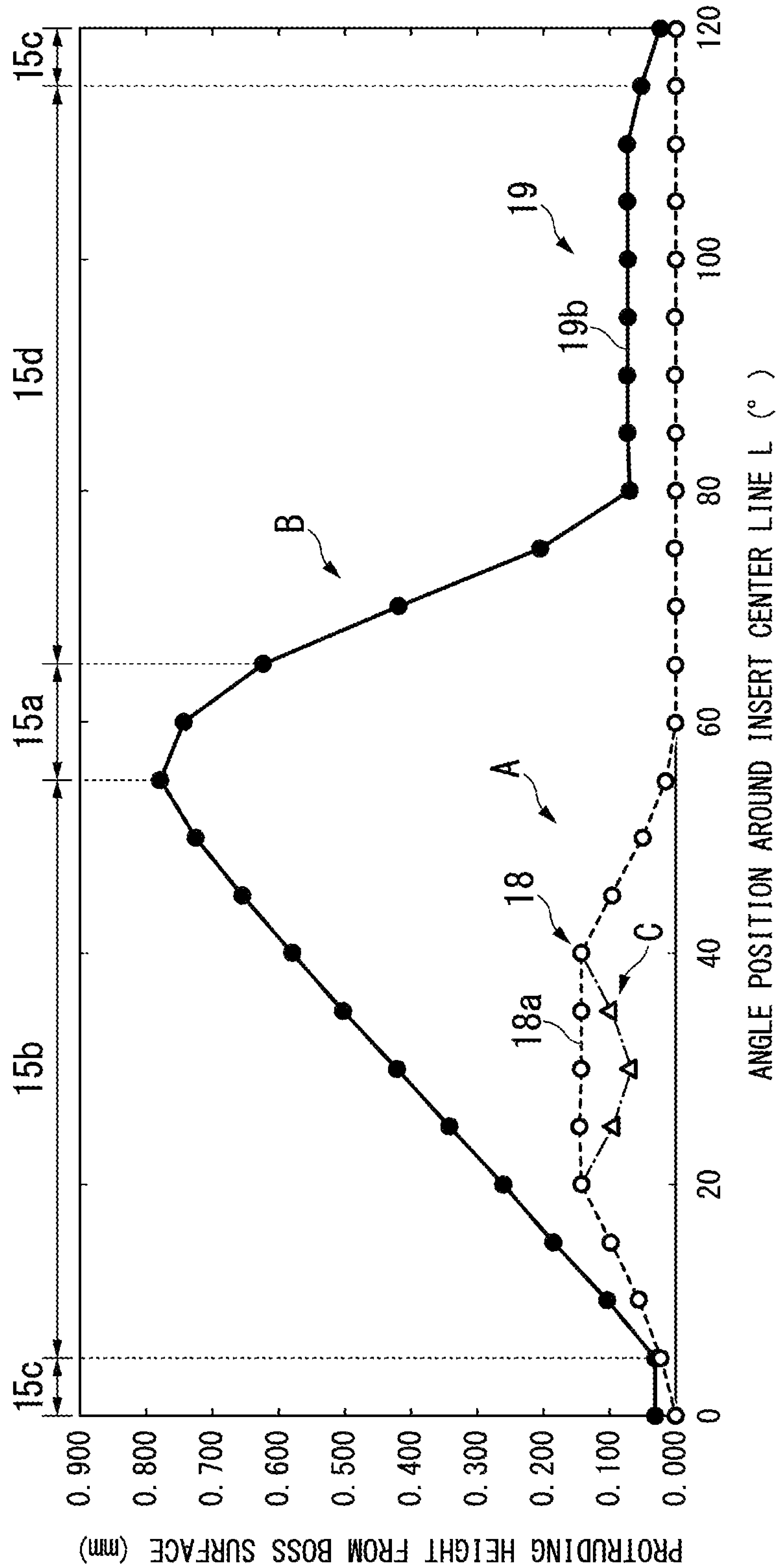

15c
15b
15a
15d
15c
B
A
C
18
18a
19
19b
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
20
40
60
80
100
120
PROTRUDING HEIGHT FROM BOSS SURFACE (mm)
ANGLE POSITION AROUND INSERT CENTER LINE L (°)

FIG. 9

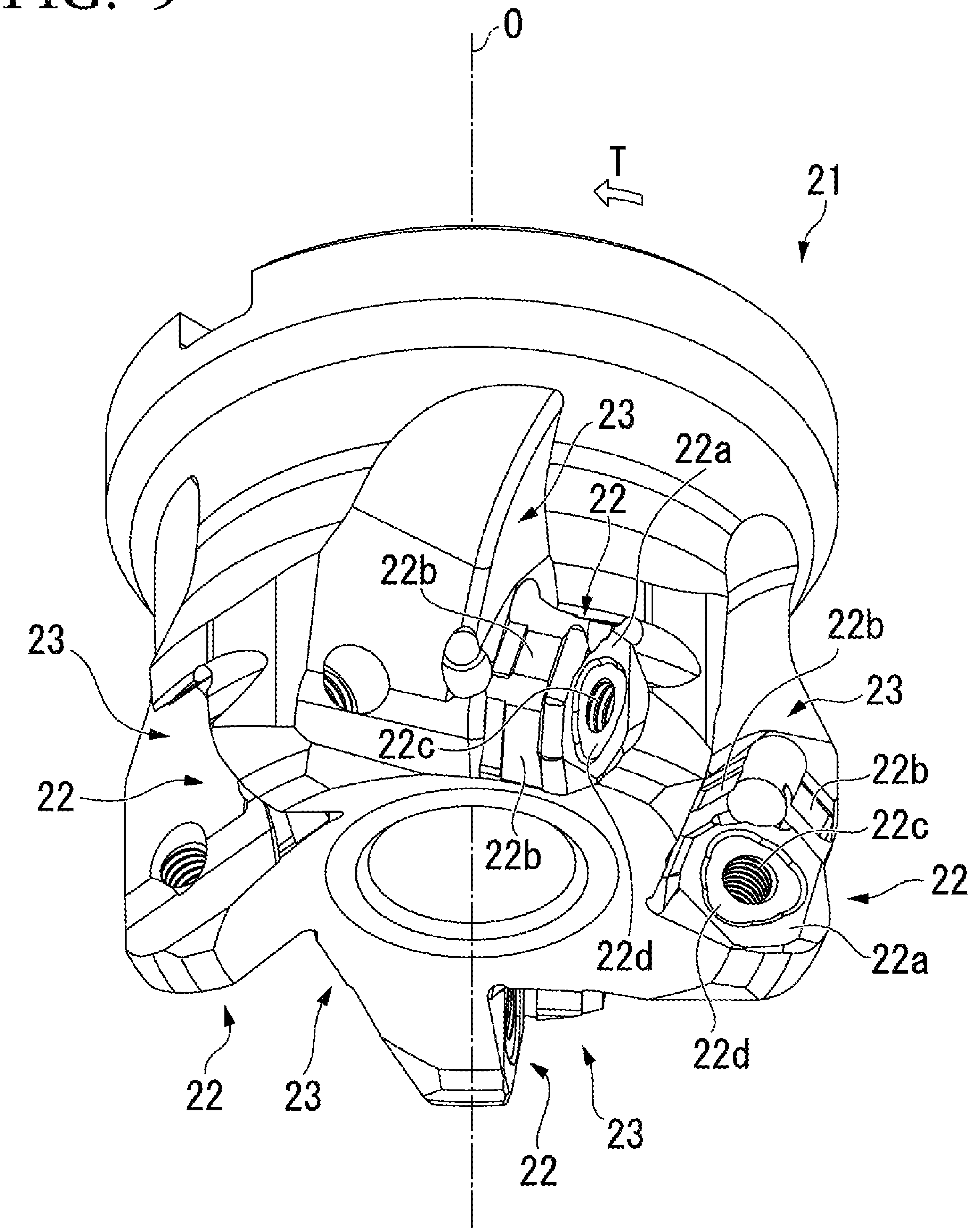

O
T
21
23
22a
22
22b
23
22b
23
22c
22b
22
22b
22c
22
22d
22a
22d
22
23
23
22

FIG. 10

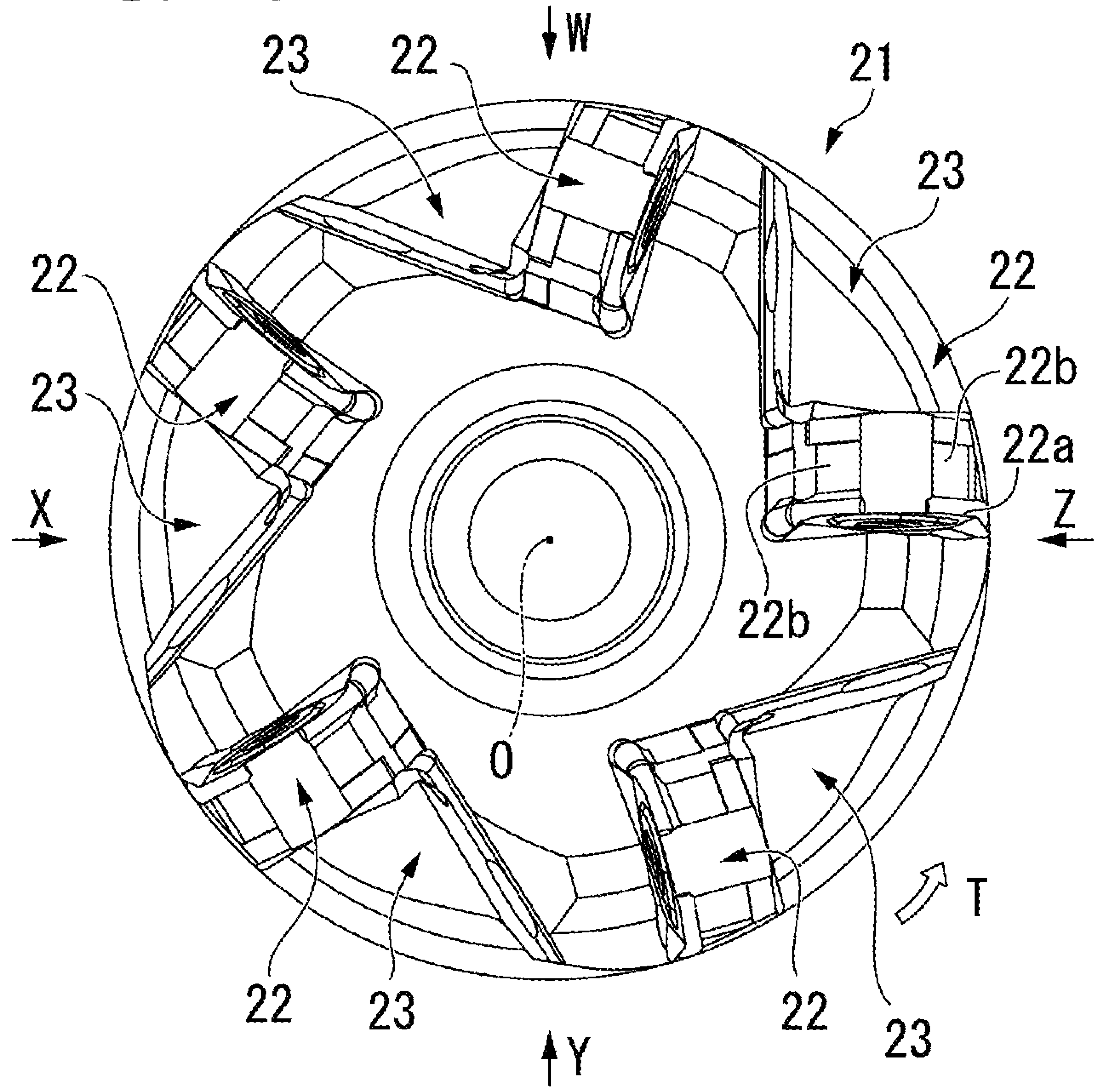


FIG. 11

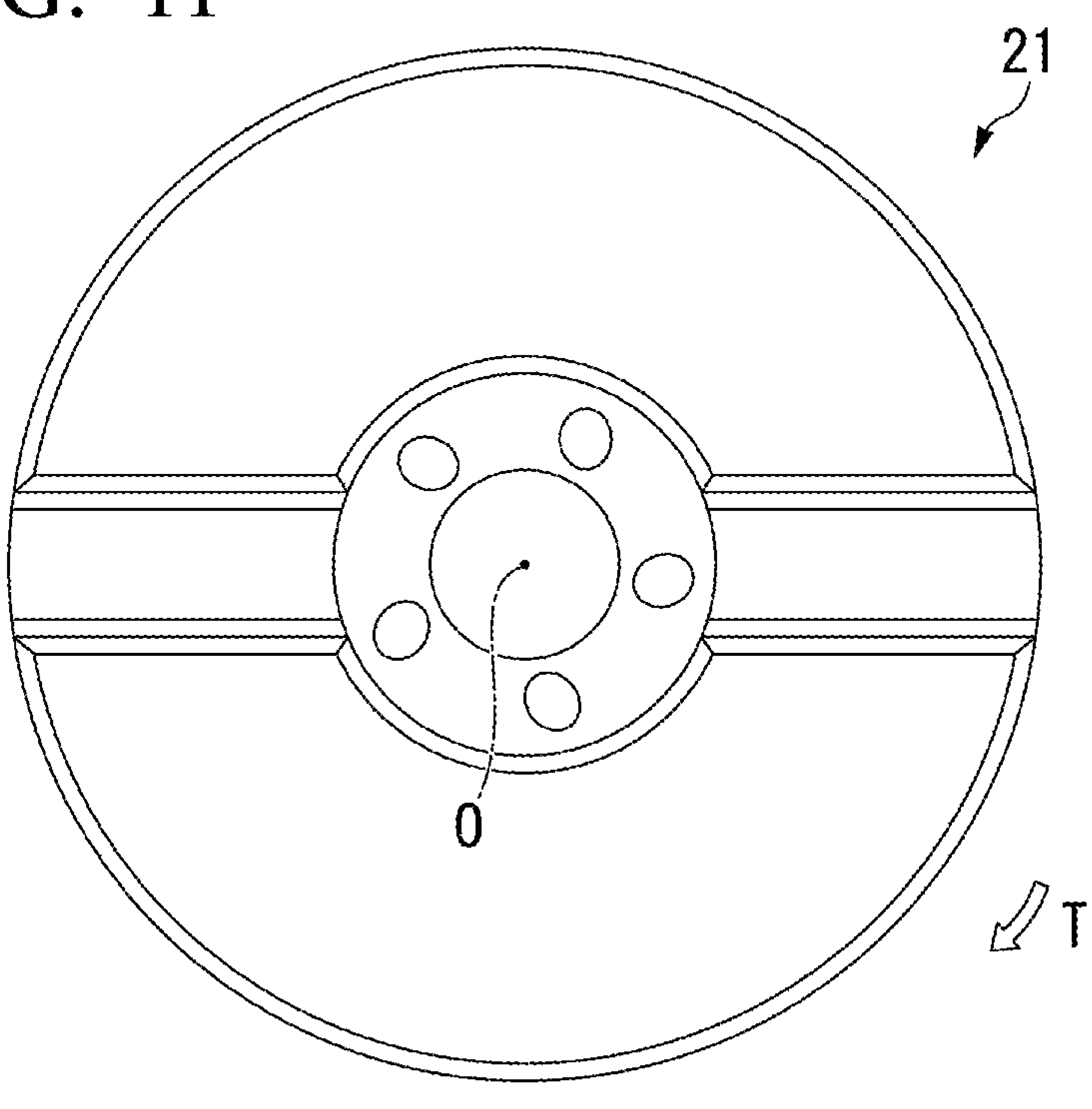


FIG. 12

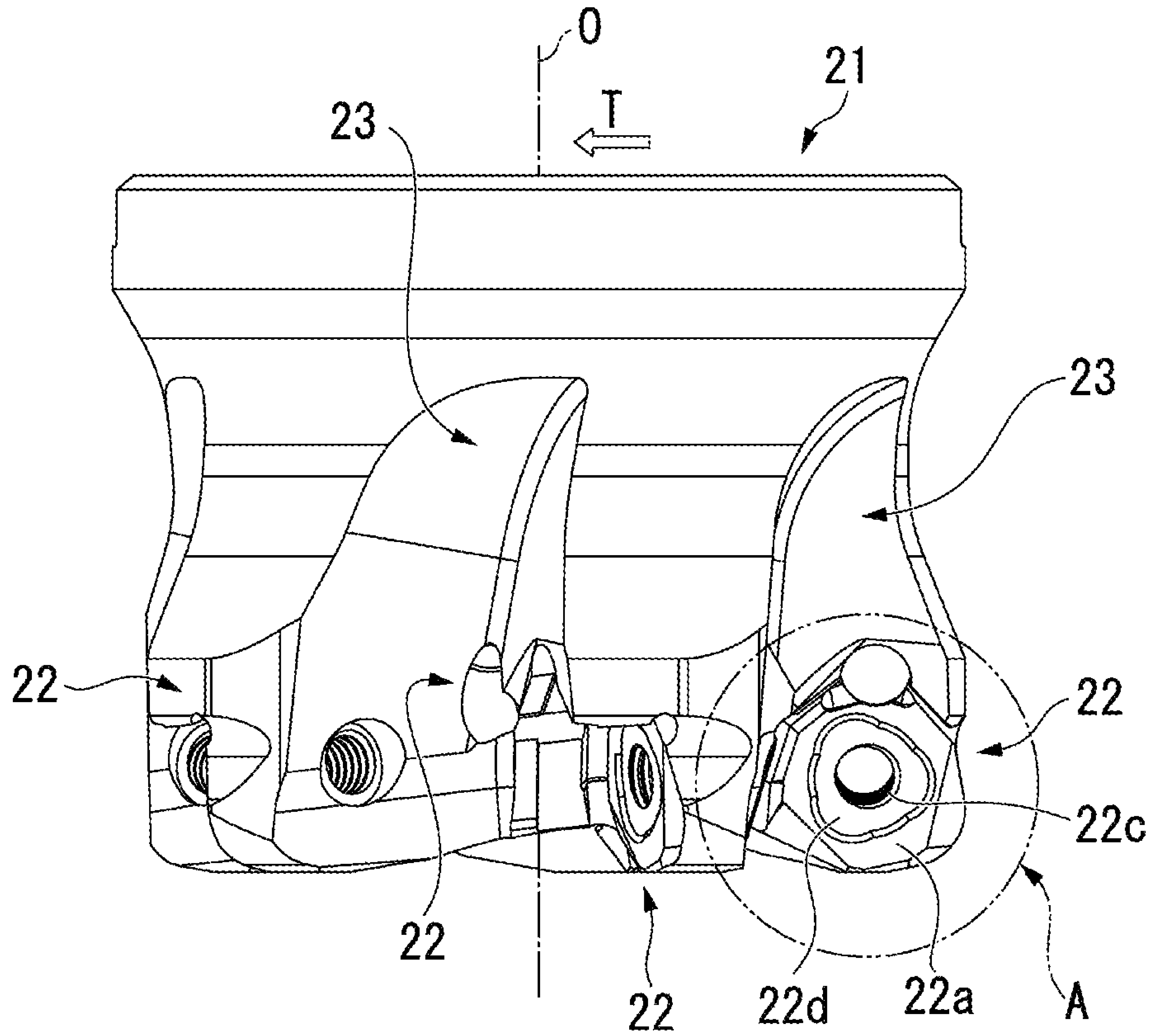


FIG. 13

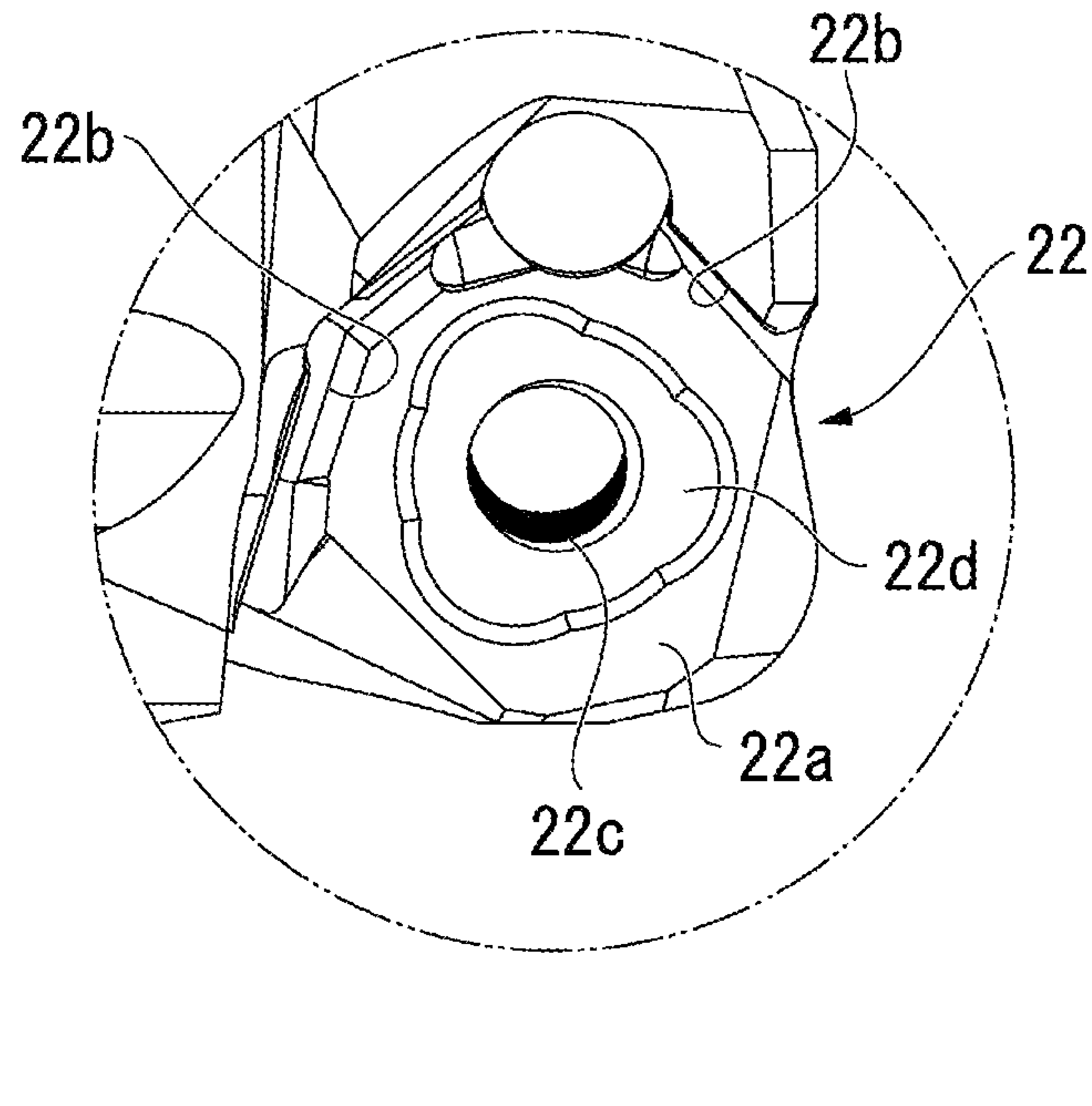


FIG. 14

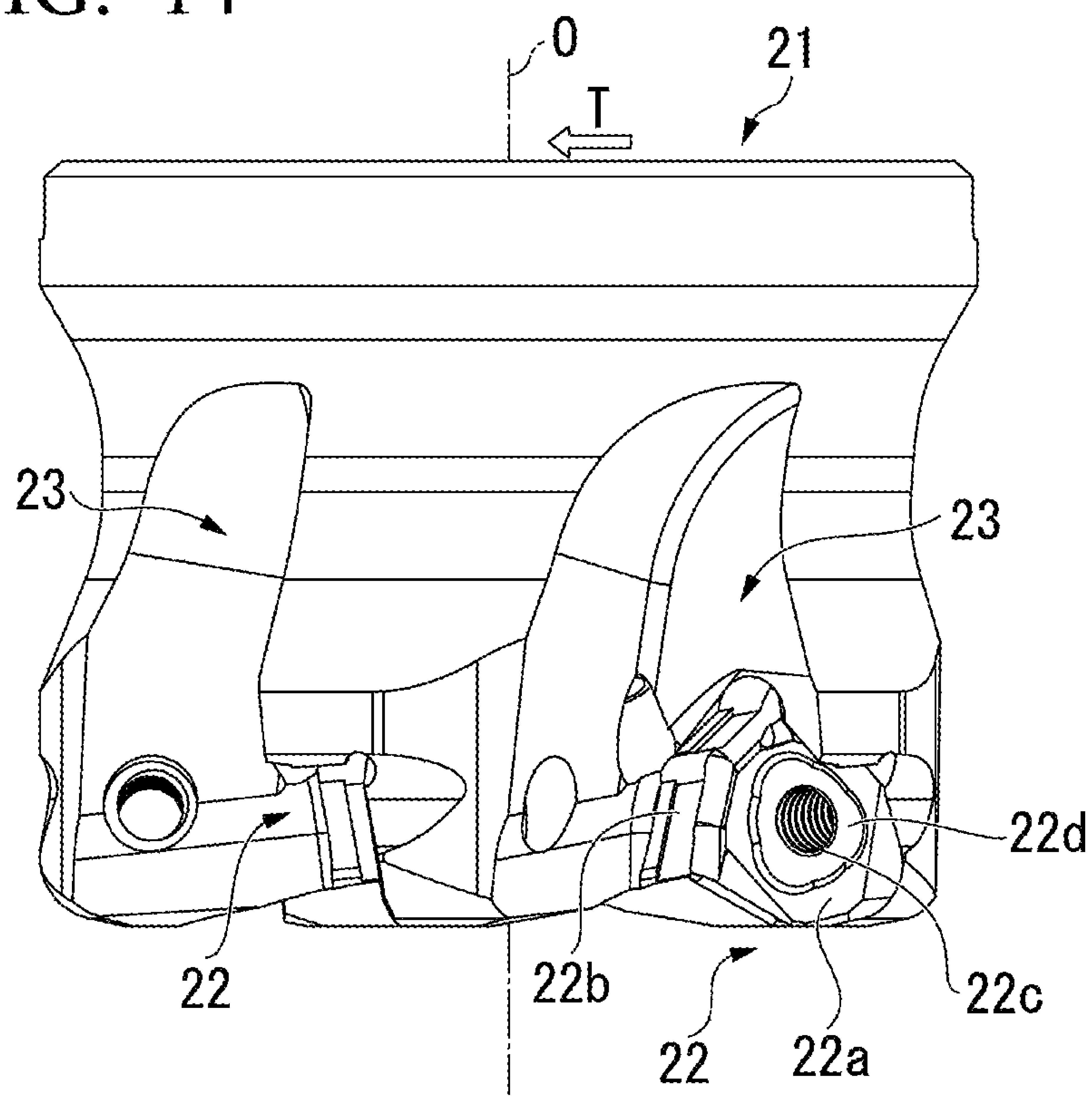

0
21
T
23
23
22d
22
22b
22c
22
22a

FIG. 15

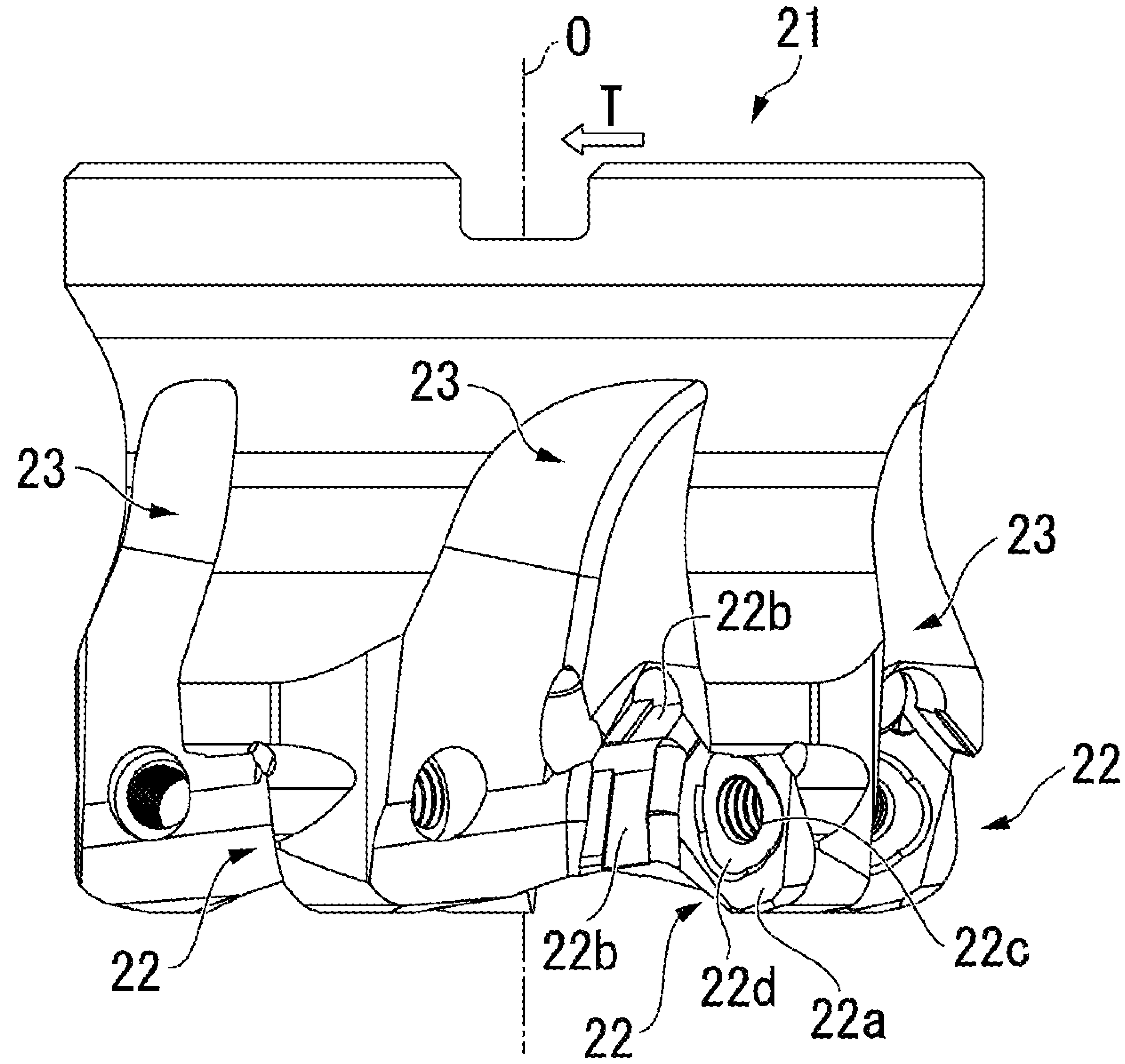

0
21
T
23
23
23
22b
22
22
22b
22c
22d
22
22a

FIG. 16

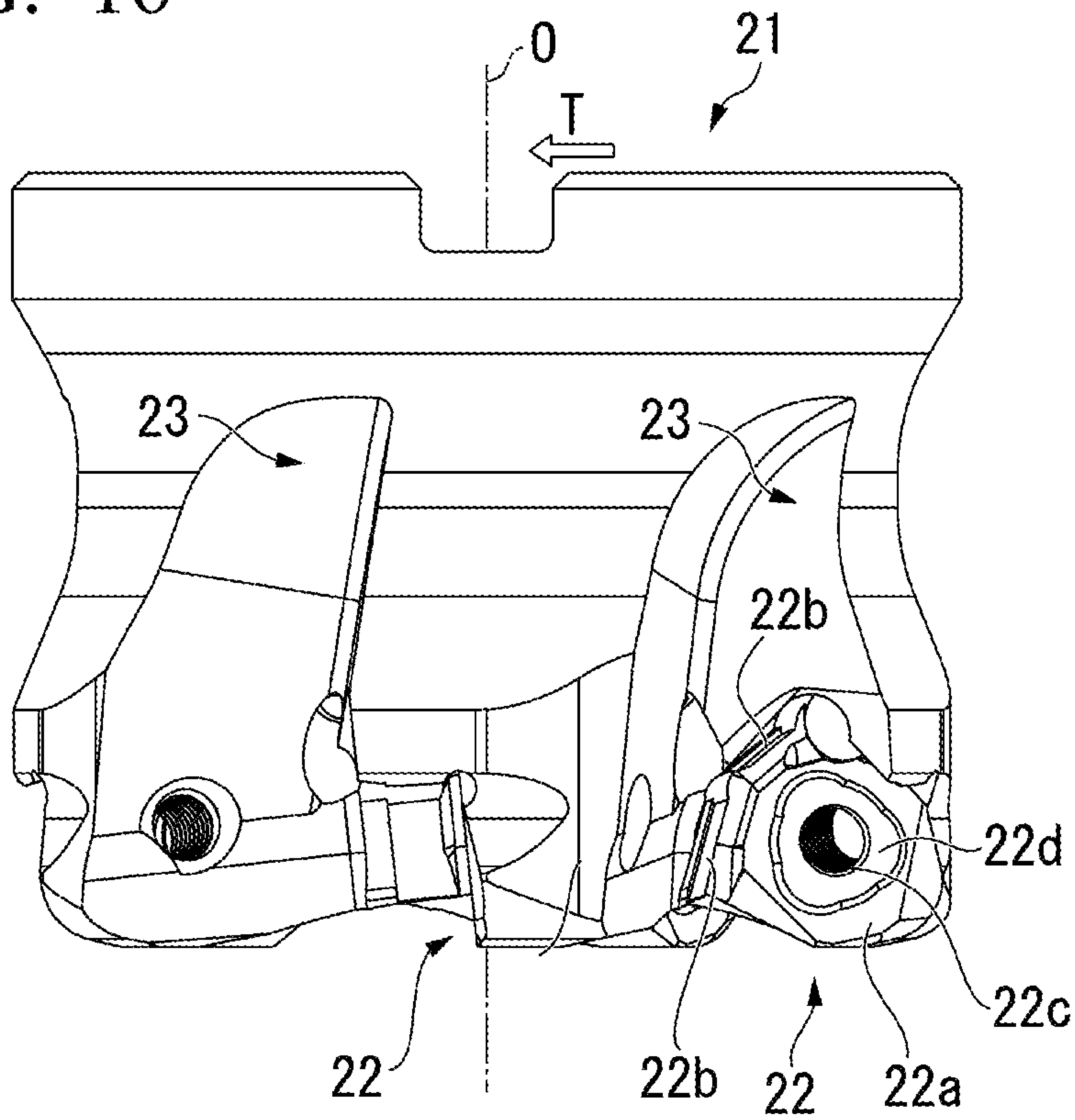


FIG. 17

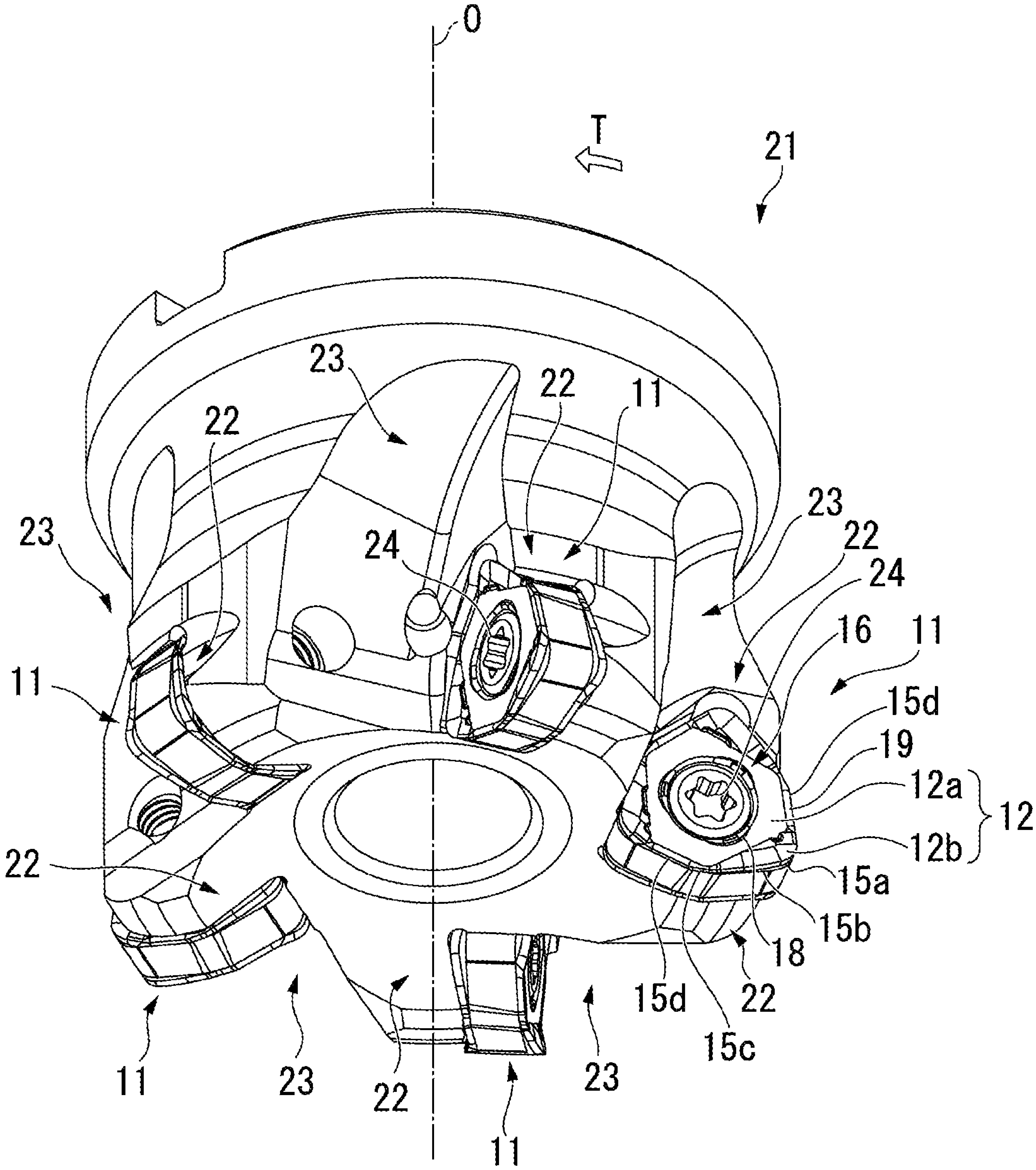

O
T
21
23
22
11
23
22
24
23
22
24
16
11
11
15d
19
12a
12
12b
15a
22
15b
18
15d
22
15c
11
23
22
11
23

FIG. 18

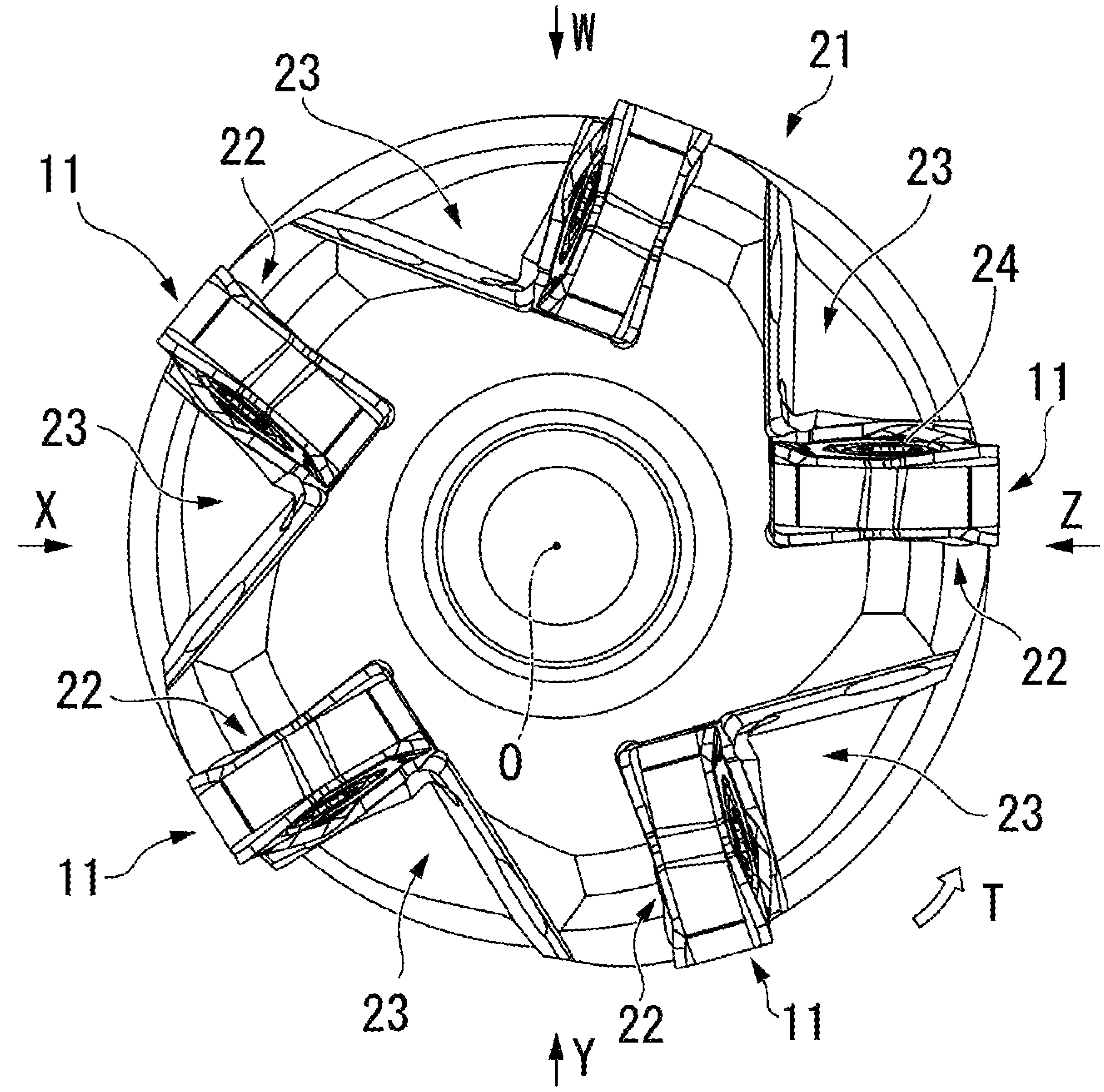

W
21
23
23
22
24
11
11
23
X
Z
22
22
O
23
11
T
23
22
11
Y

FIG. 19

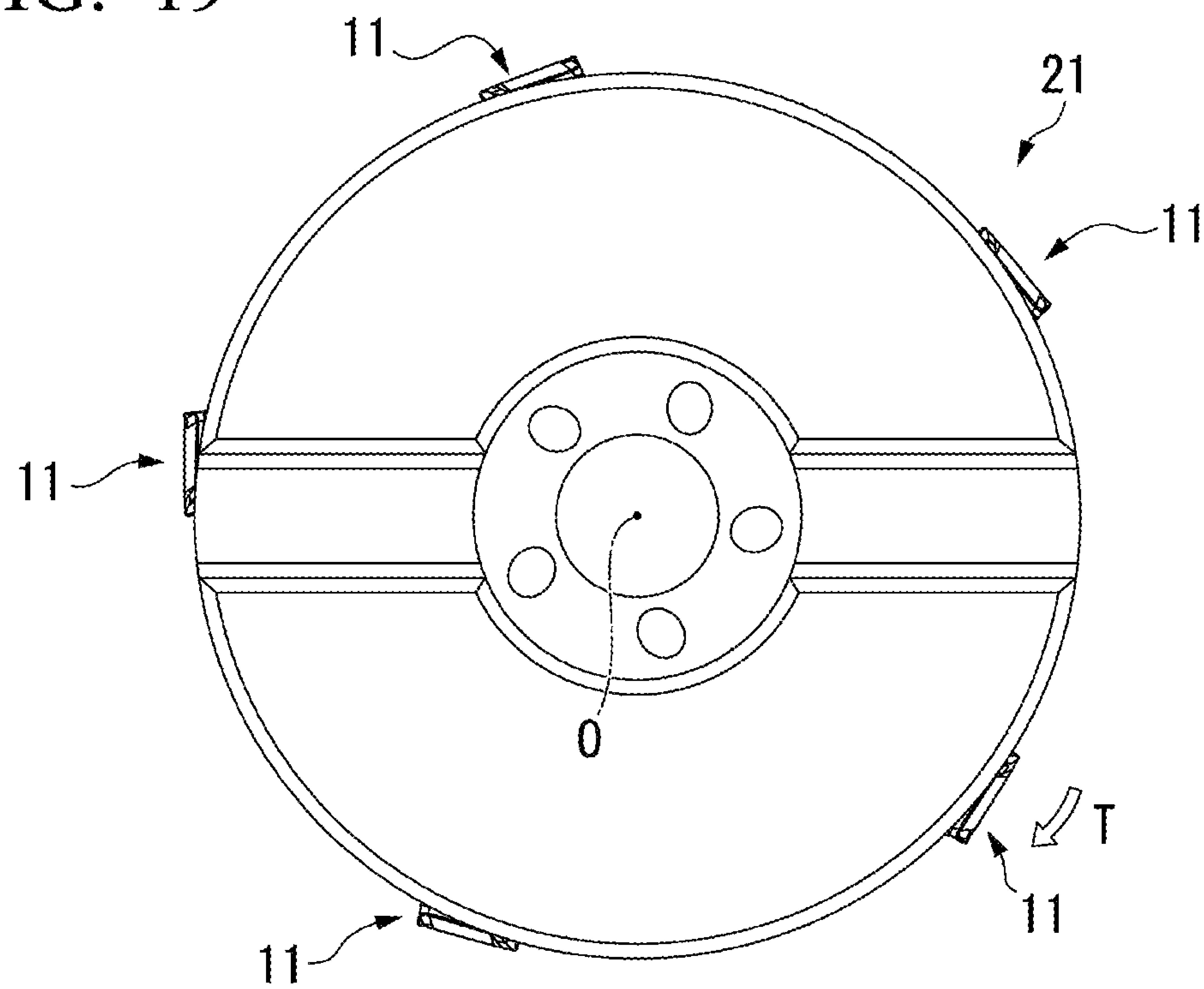

11
21
11
11
O
T
11
11

FIG. 20

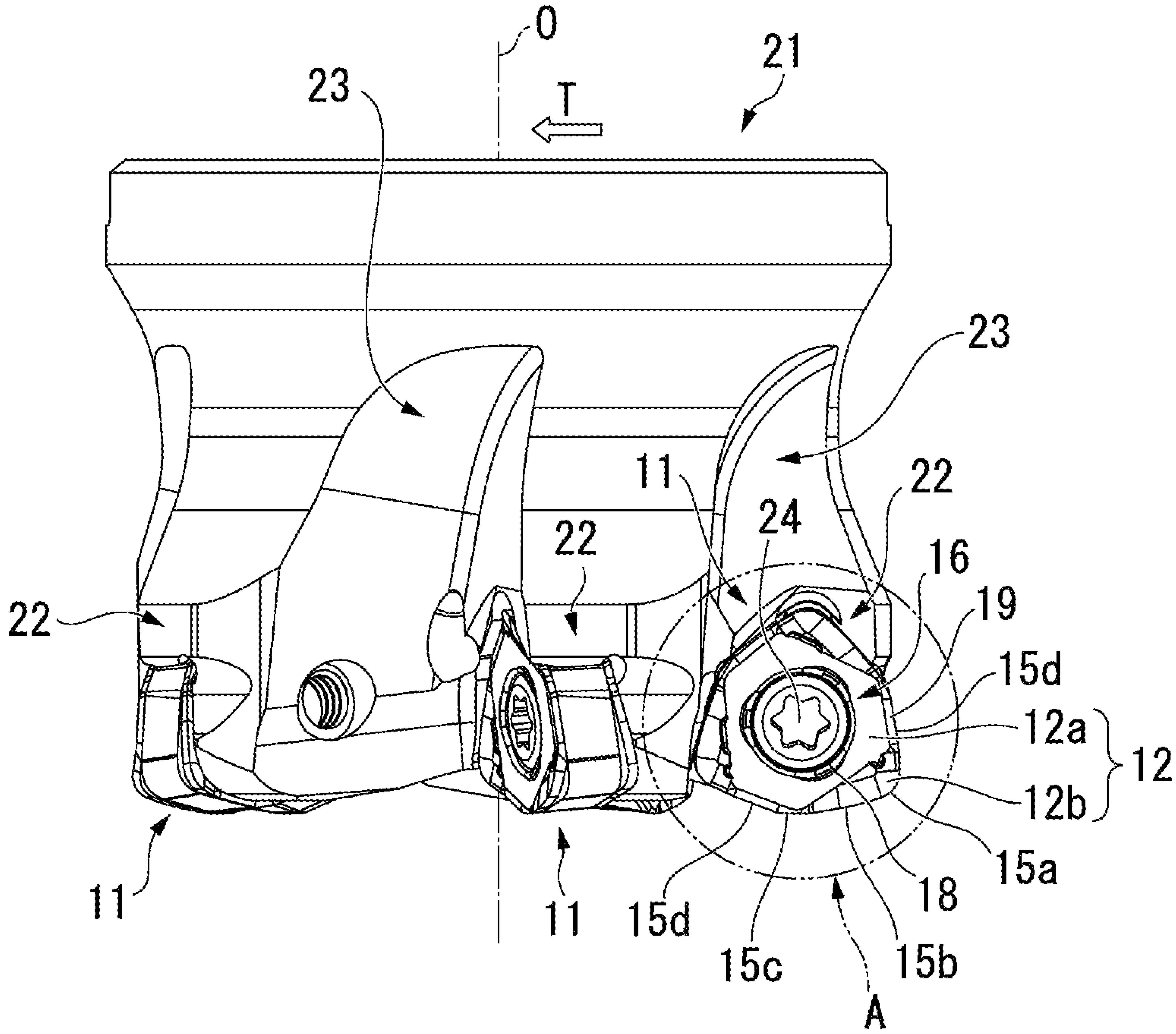

0
21
23
T
23
11
24
22
22
16
19
22
15d
12a
12
12b
15a
18
11
11
15d
15c
15b
A

FIG. 21

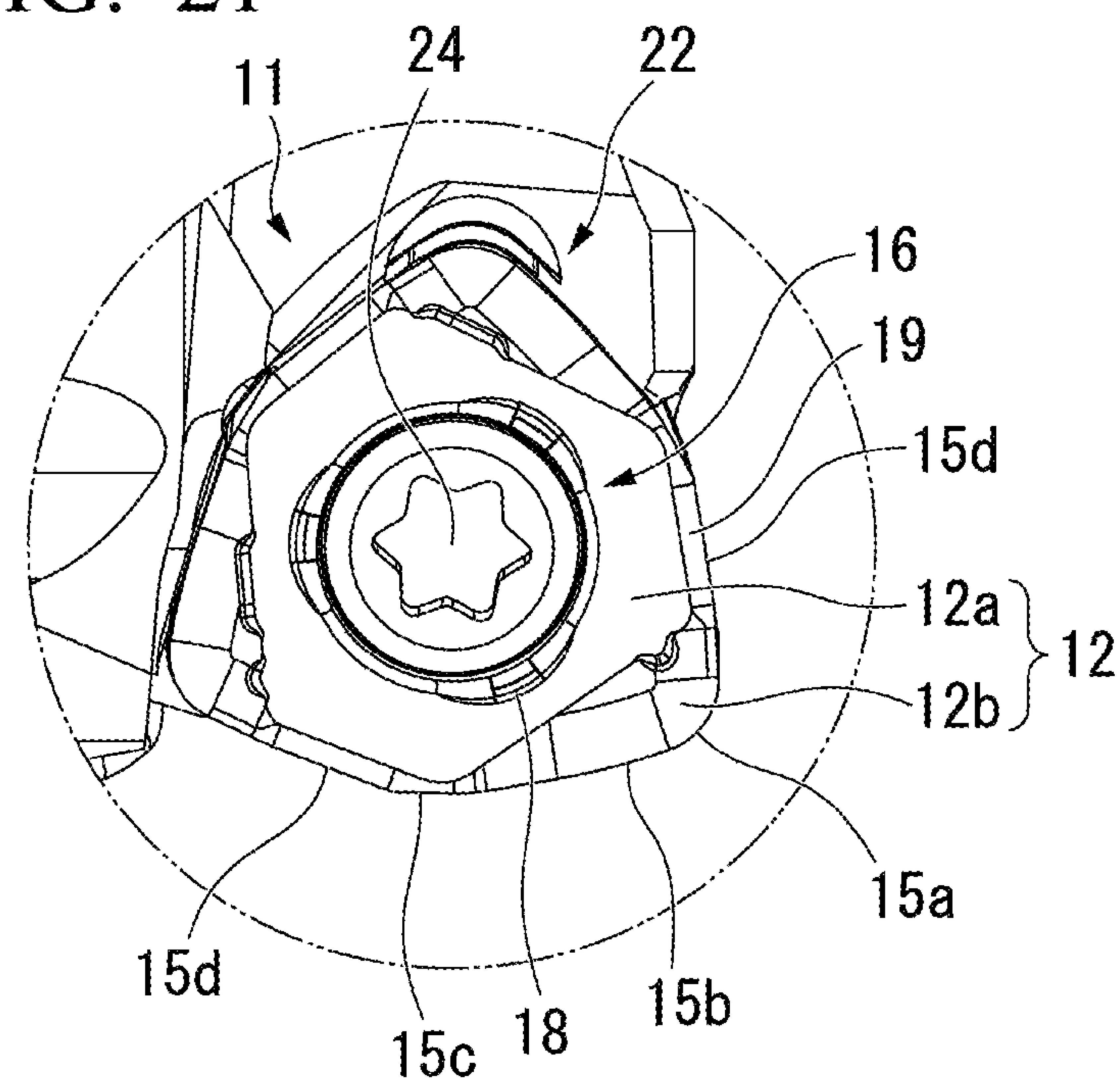

11
24
22
16
19
15d
12a
12
12b
15a
15d
15c
18
15b

FIG. 22

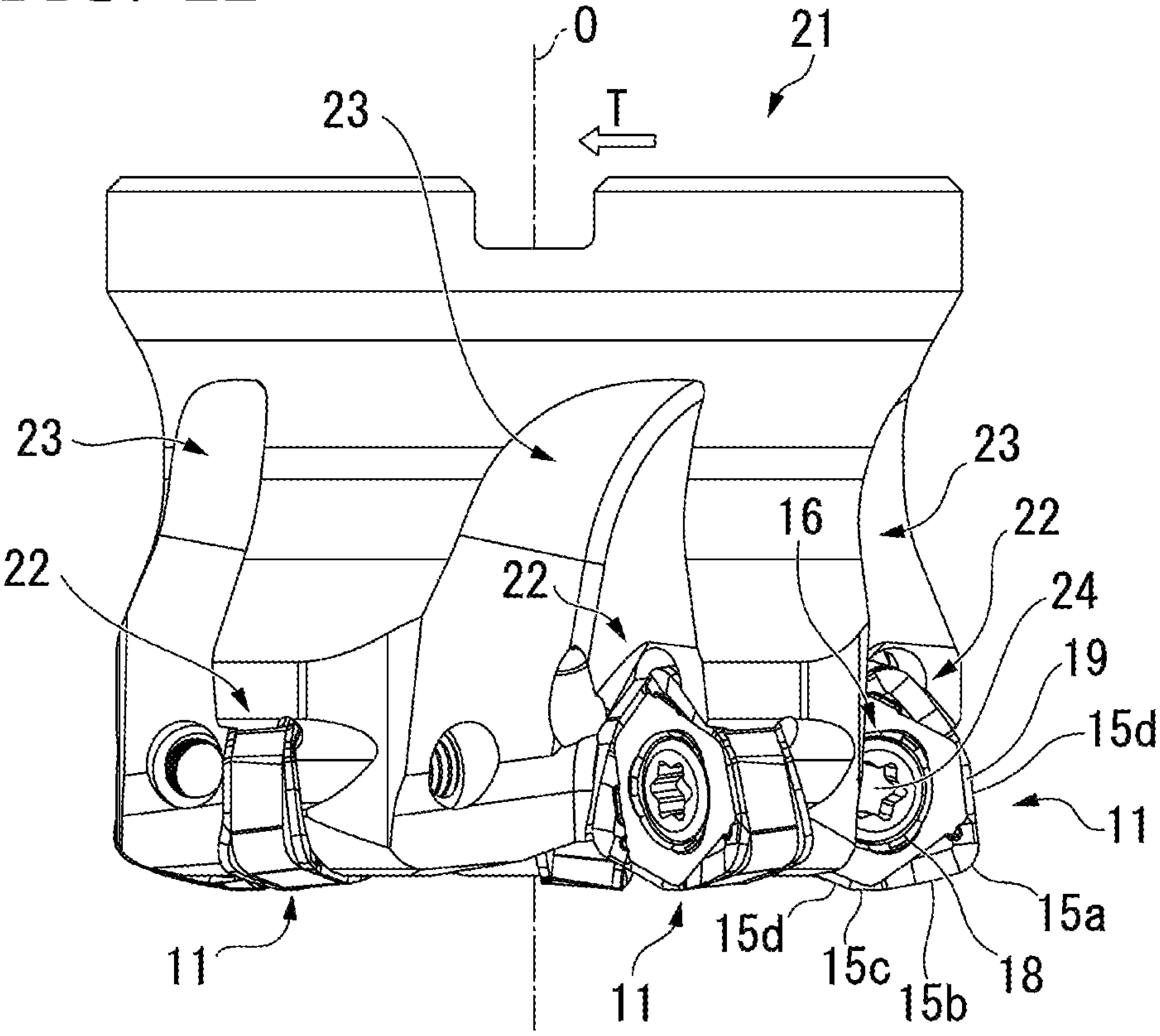

0
21
T
23
23
23
16
22
22
22
24
19
15d
11
11
11
15d
15c
15b
15a
18

FIG. 23

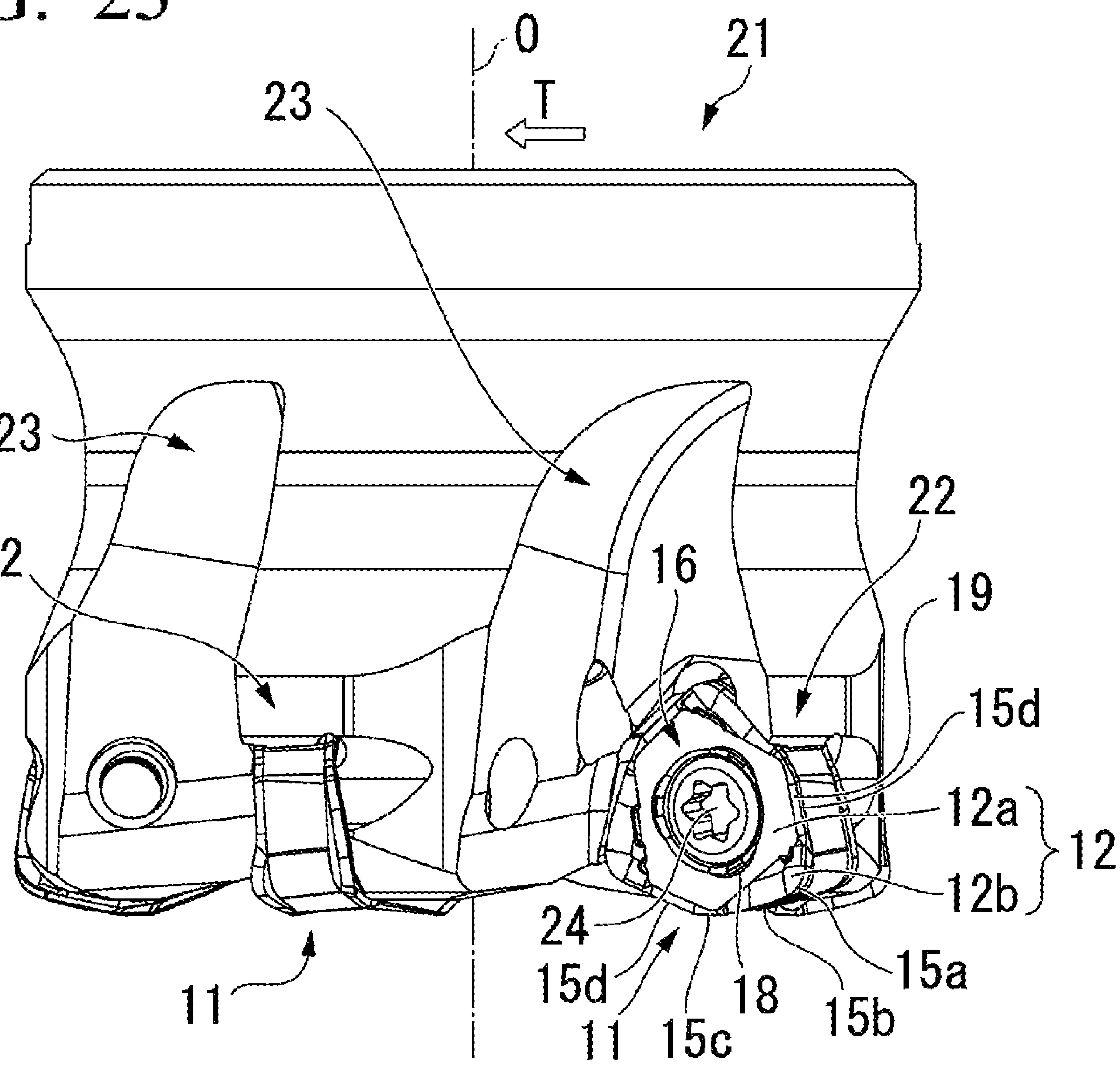

0
21
T
23
23
22
16
22
19
15d
12a
12
12b
24
15d
11
11
15c
18
15b
15a

FIG. 24

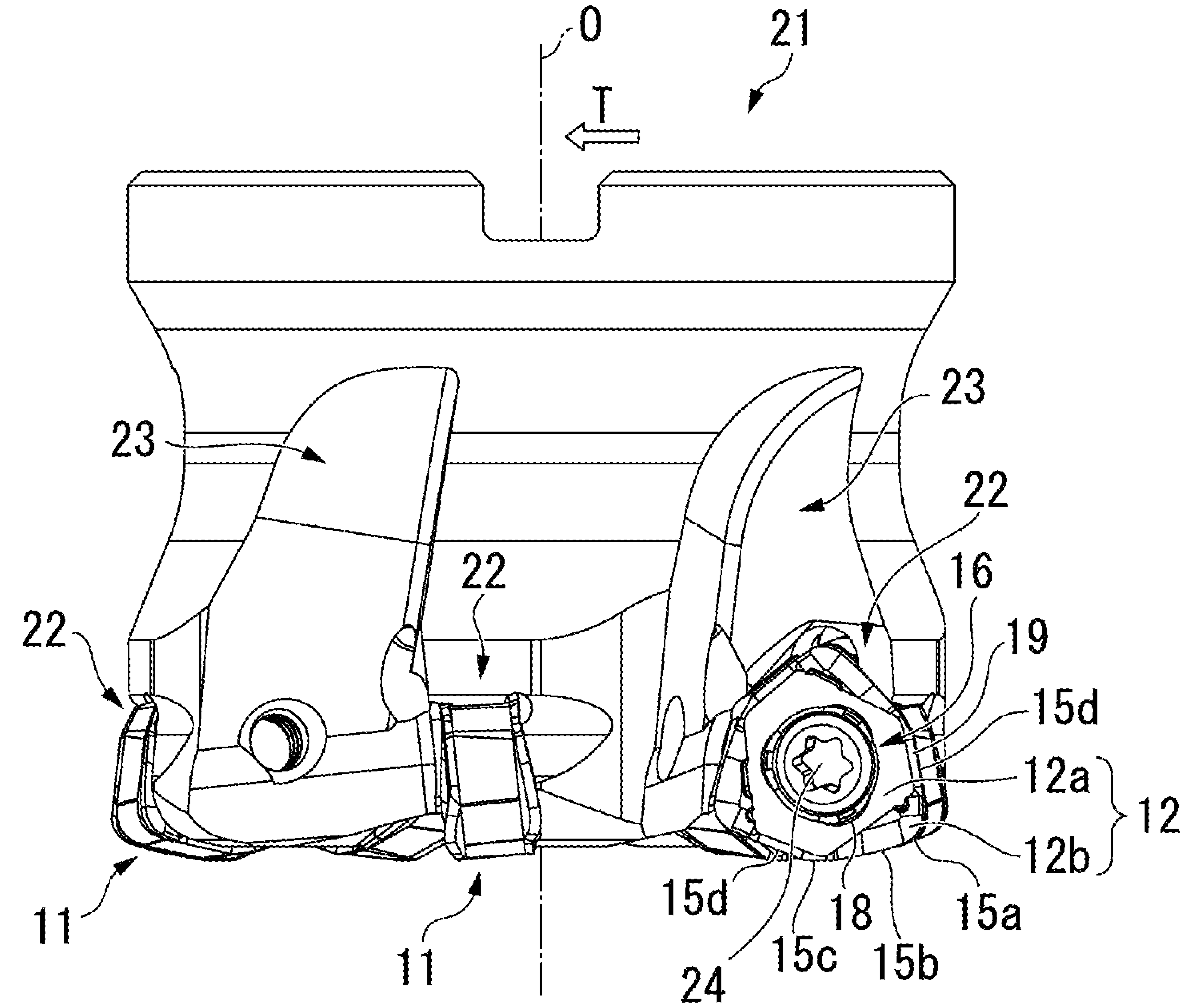


FIG. 25

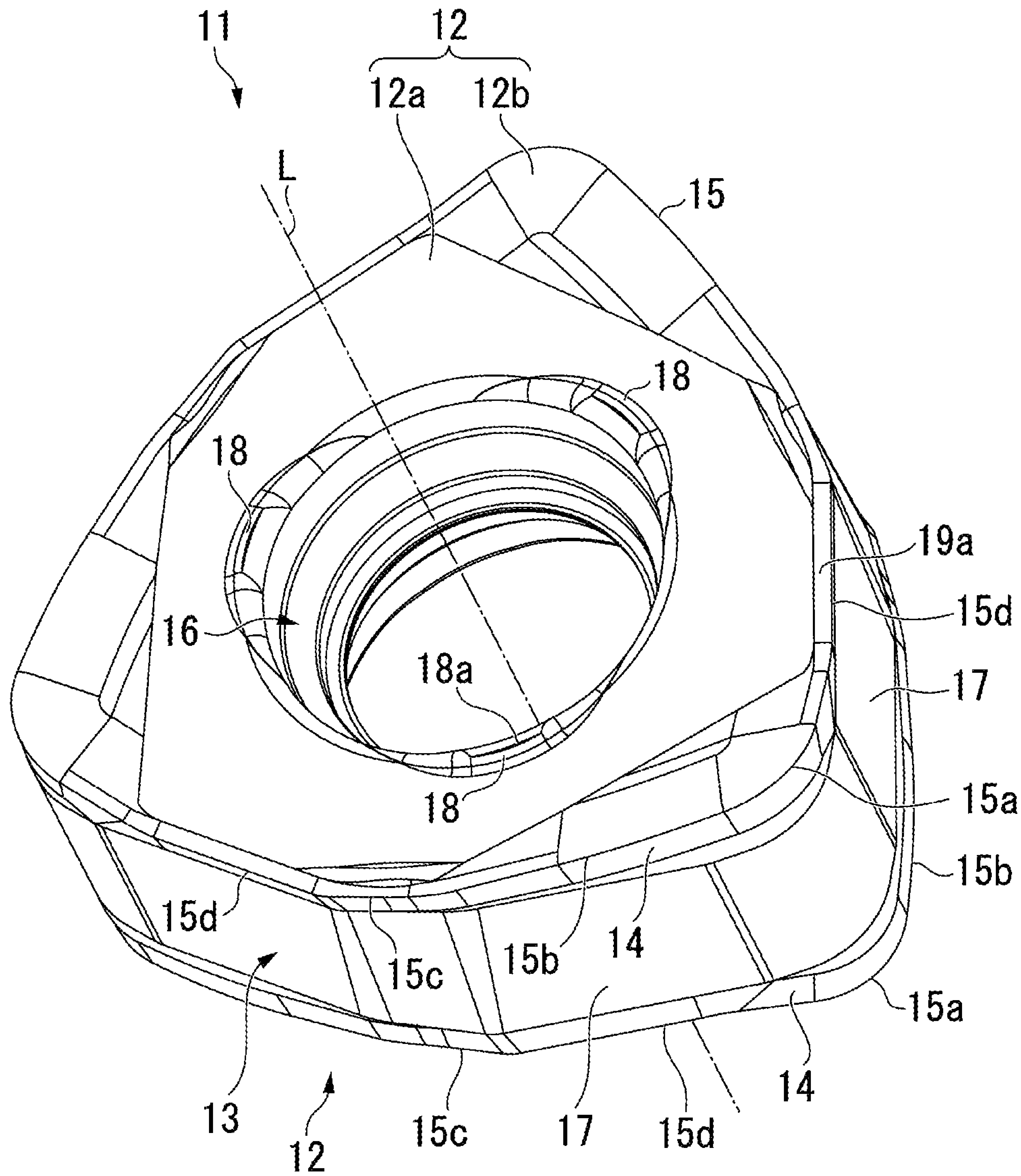

11
12
12a
12b
L
15
18
18
19a
15d
16
18a
17
15a
18
15b
15d
15c
15b
14
13
15c
17
15d
14
15a
12

FIG. 26

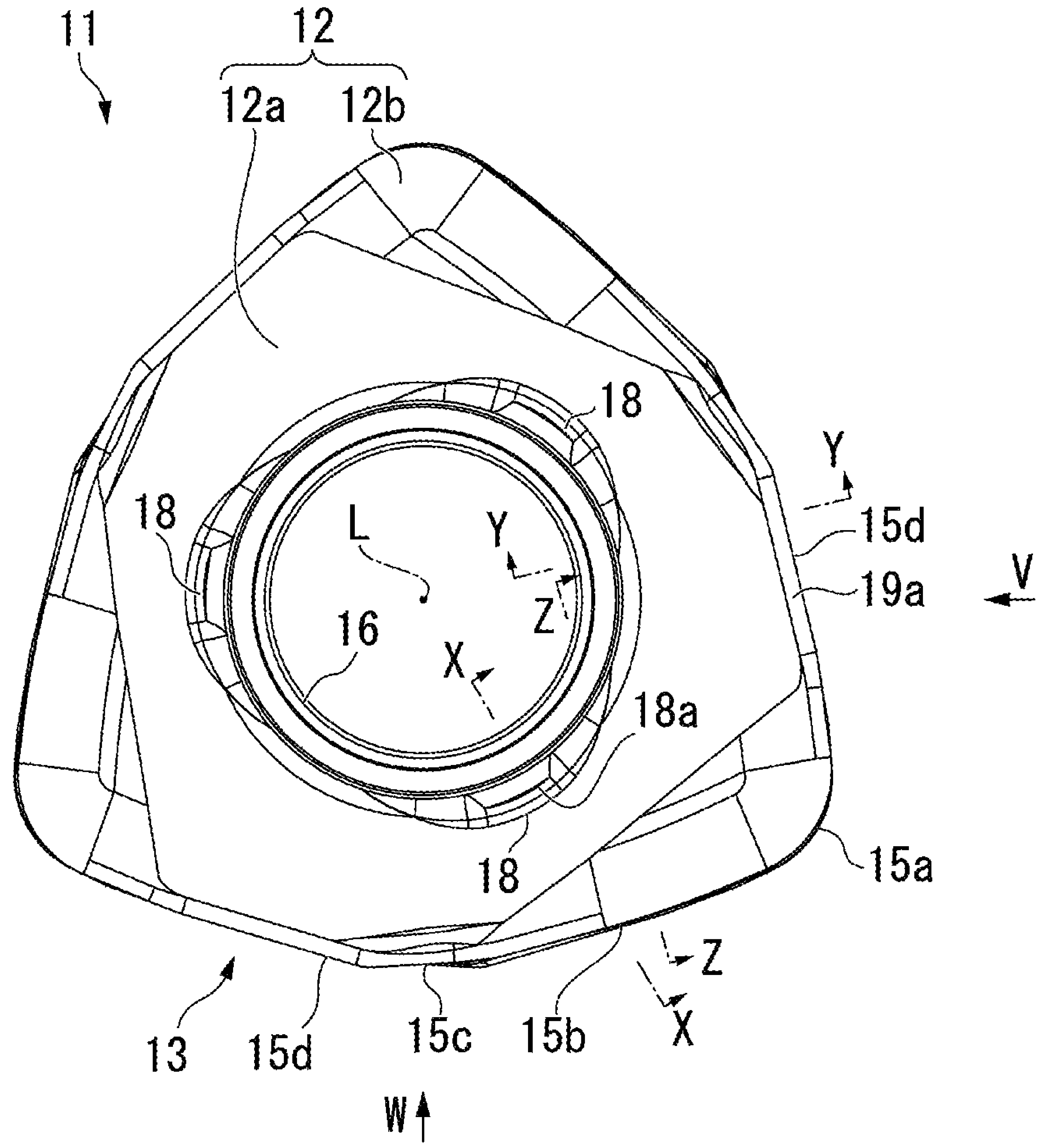

11
12
12a
12b
18
18
Y
15d
V
19a
L
Y
Z
16
X
18a
18
15a
Z
13
15d
15c
15b
X
W

FIG. 27

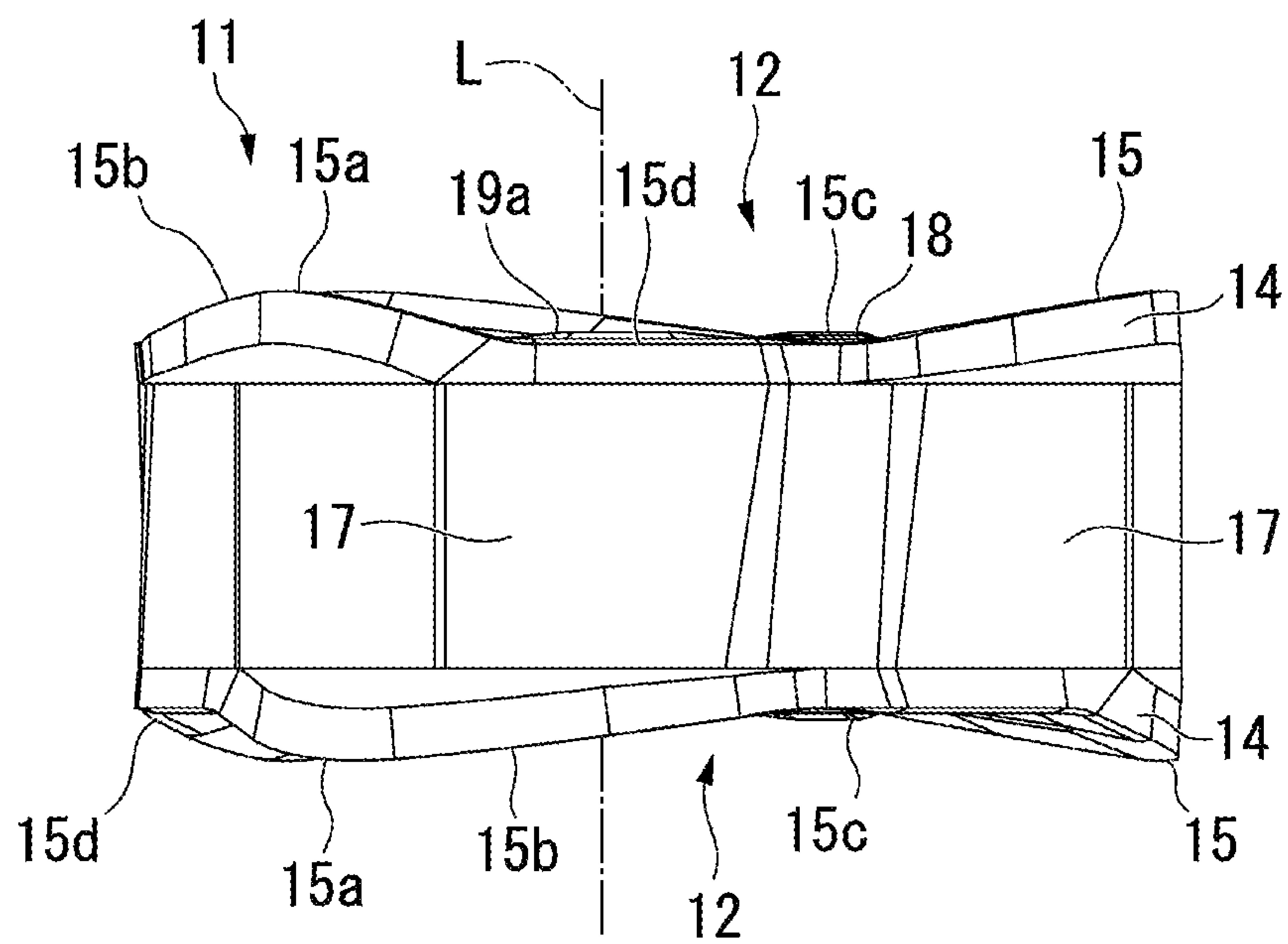

11
L
12
15b
15a
19a
15d
15c
18
15
14
17
17
14
15d
15a
15b
15c
15
12

FIG. 28

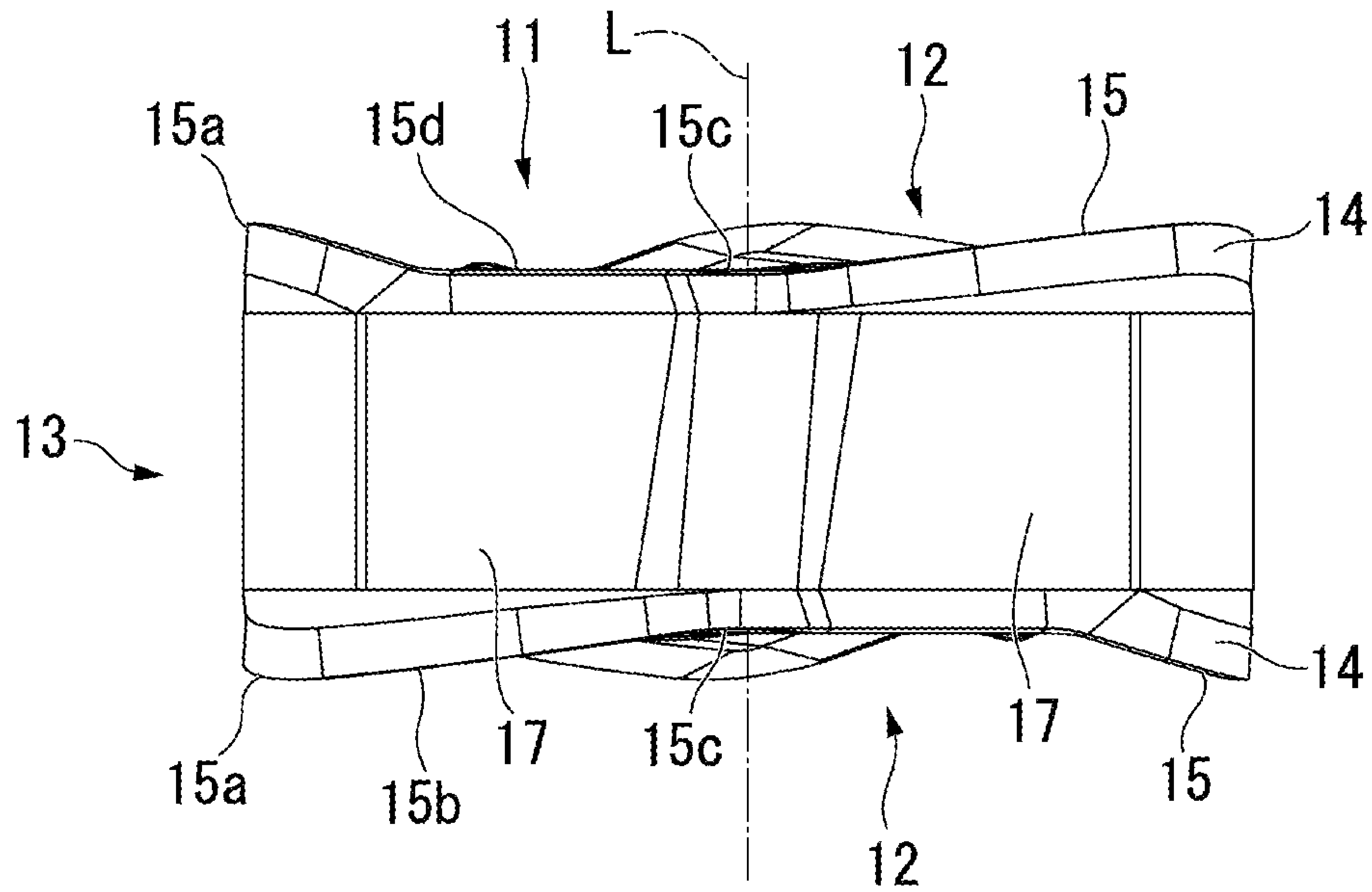

11
L
12
15
15a
15d
15c
14
13
17
15c
17
14
15a
15b
15c
12
15

FIG. 29

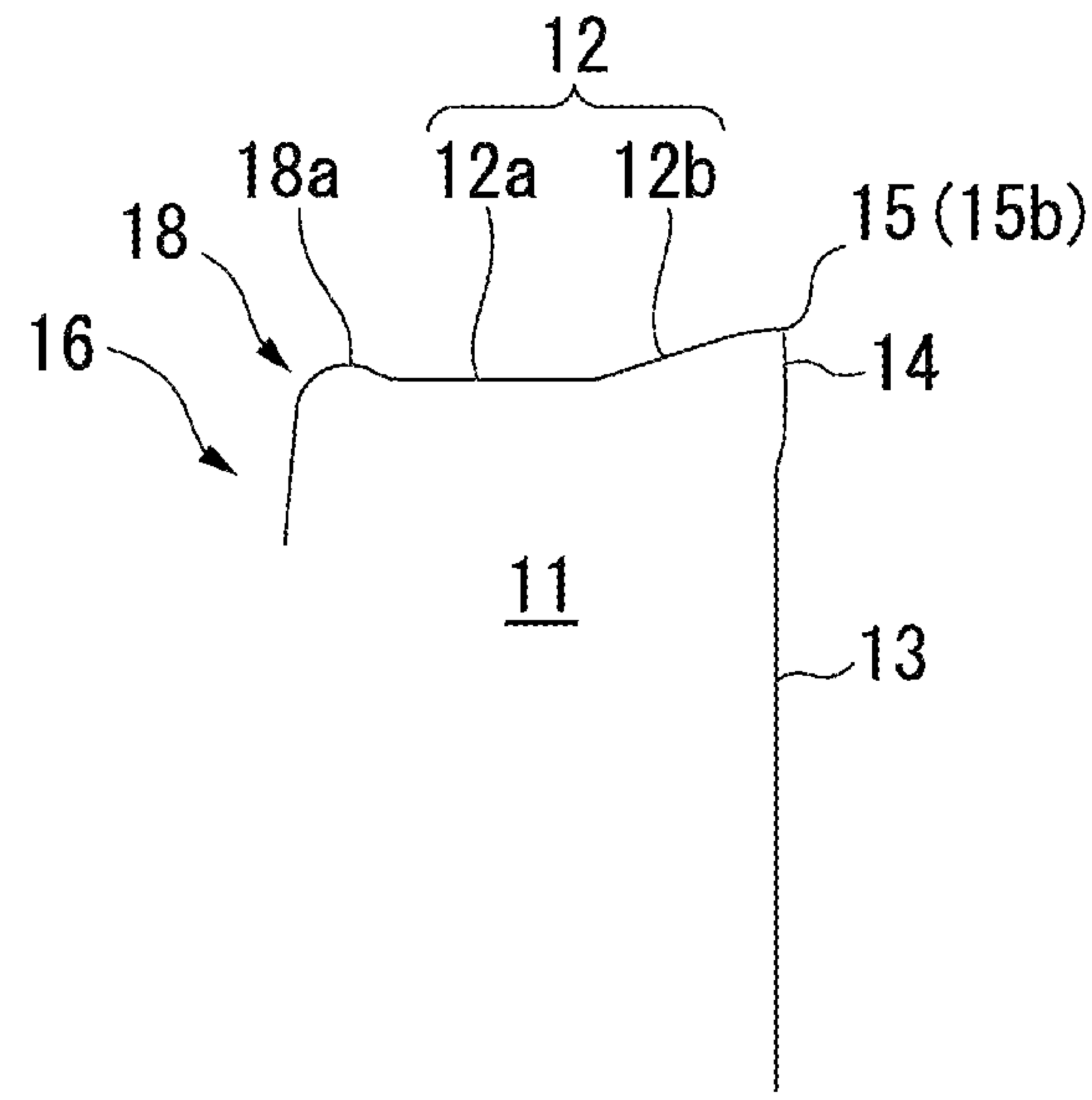

12
18a
12a
12b
15 (15b)
18
16
14
11
13

FIG. 30

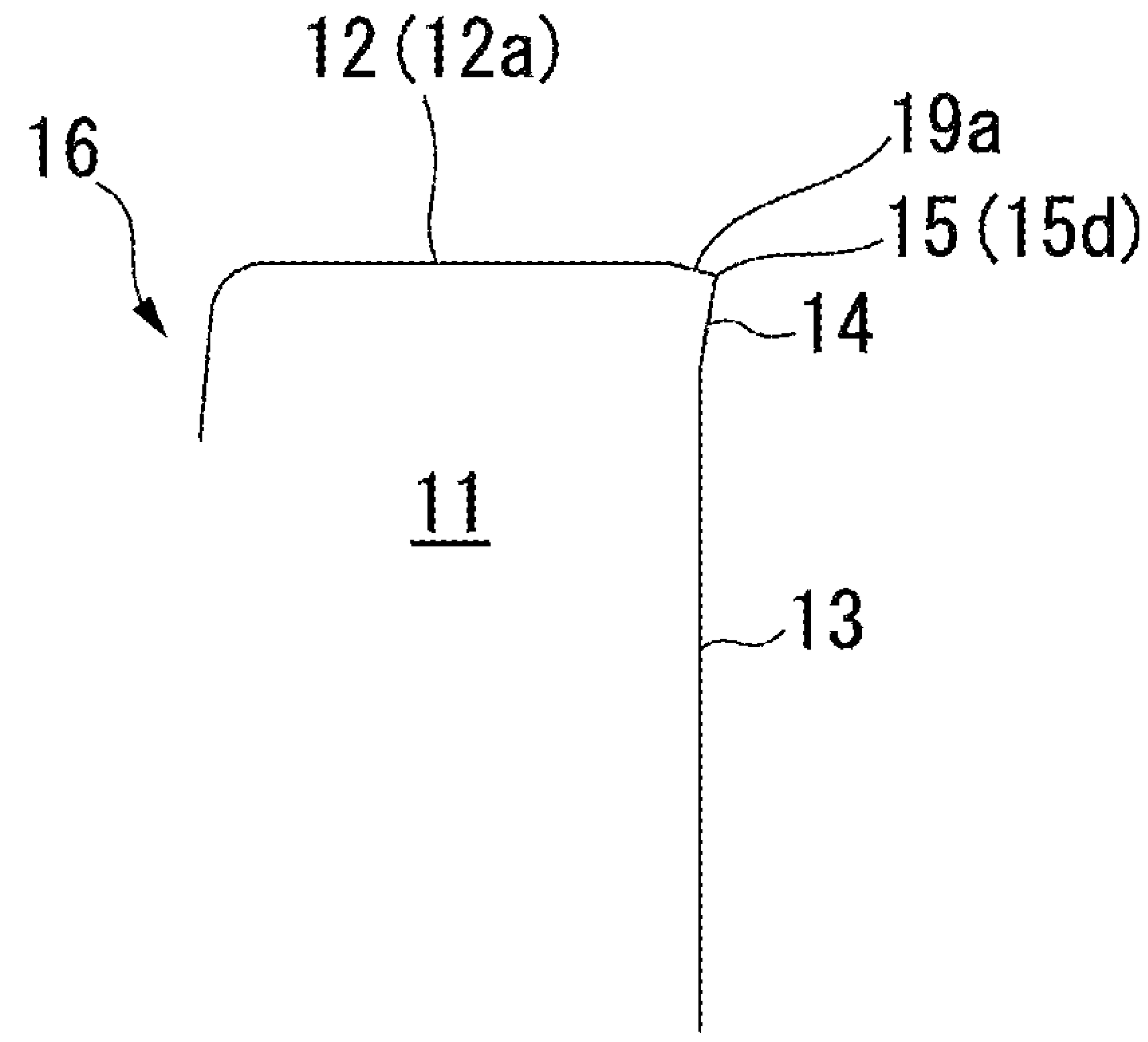


FIG. 31

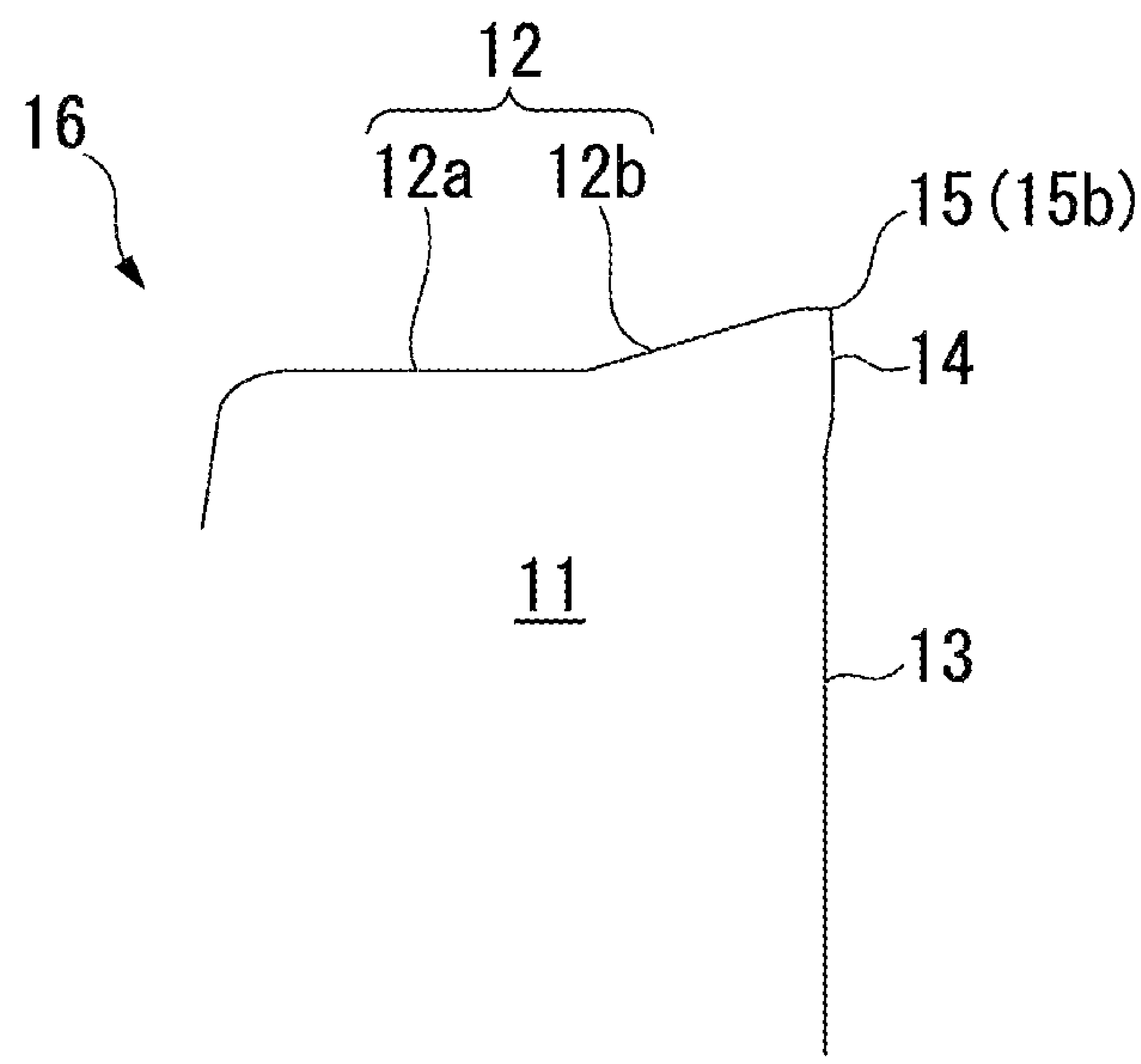


FIG. 32

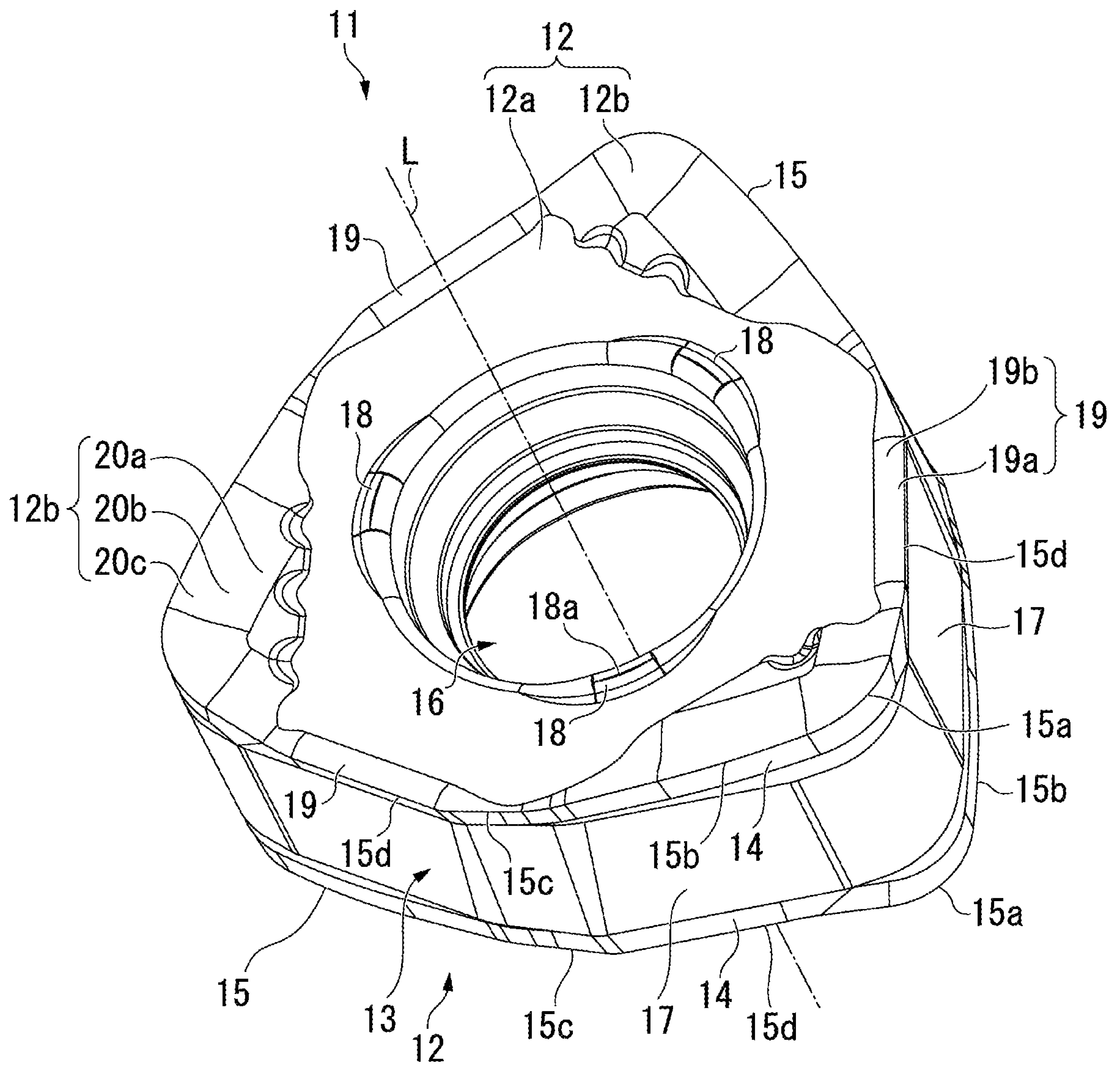

11
12
12a
12b
L
15
19
18
19b
19
18
19a
20a
12b
20b
15d
20c
18a
17
16
15a
18
15b
19
14
15b
15d
15c
15a
15
13
15c
17
14
15d
12

FIG. 33

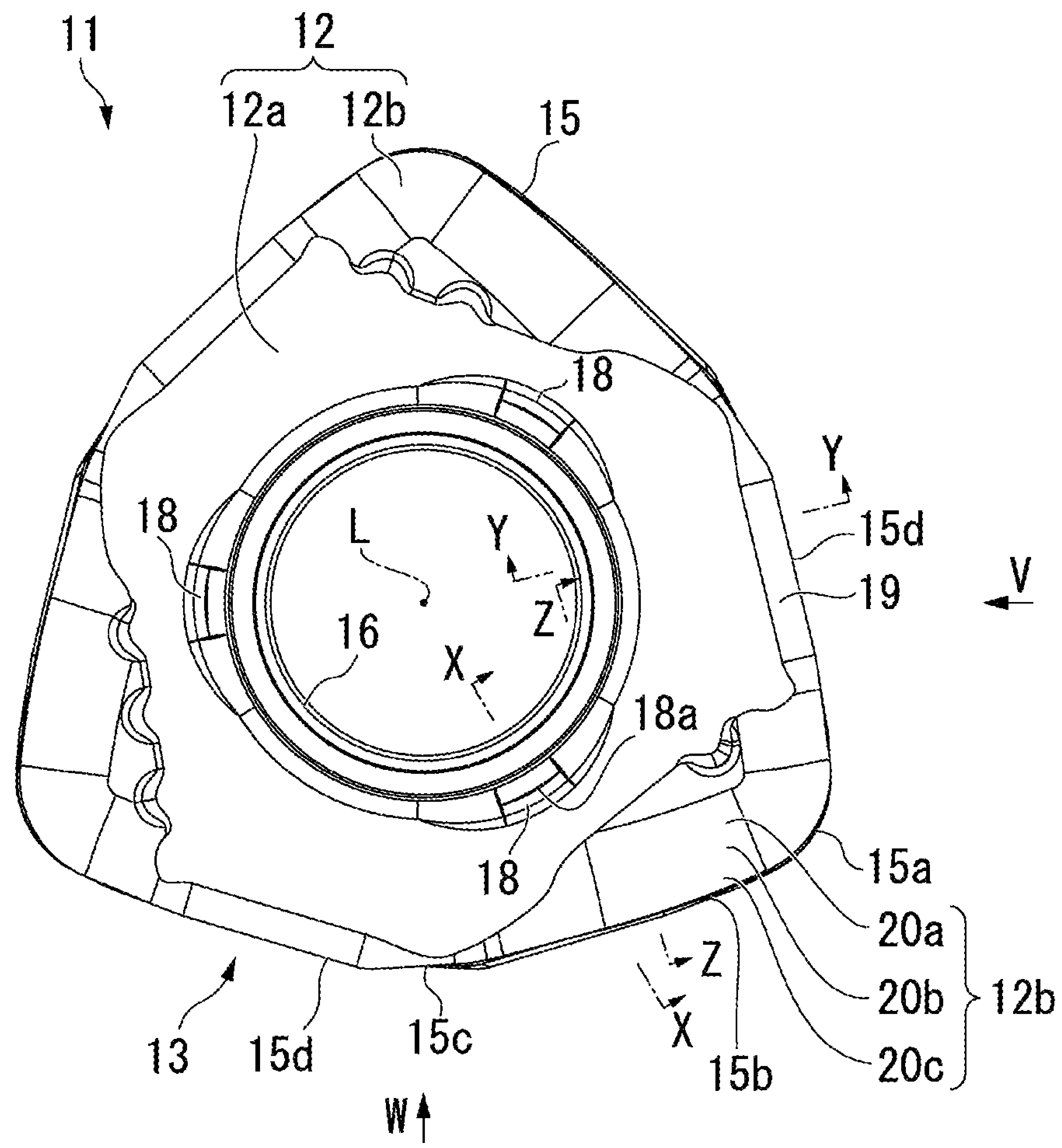
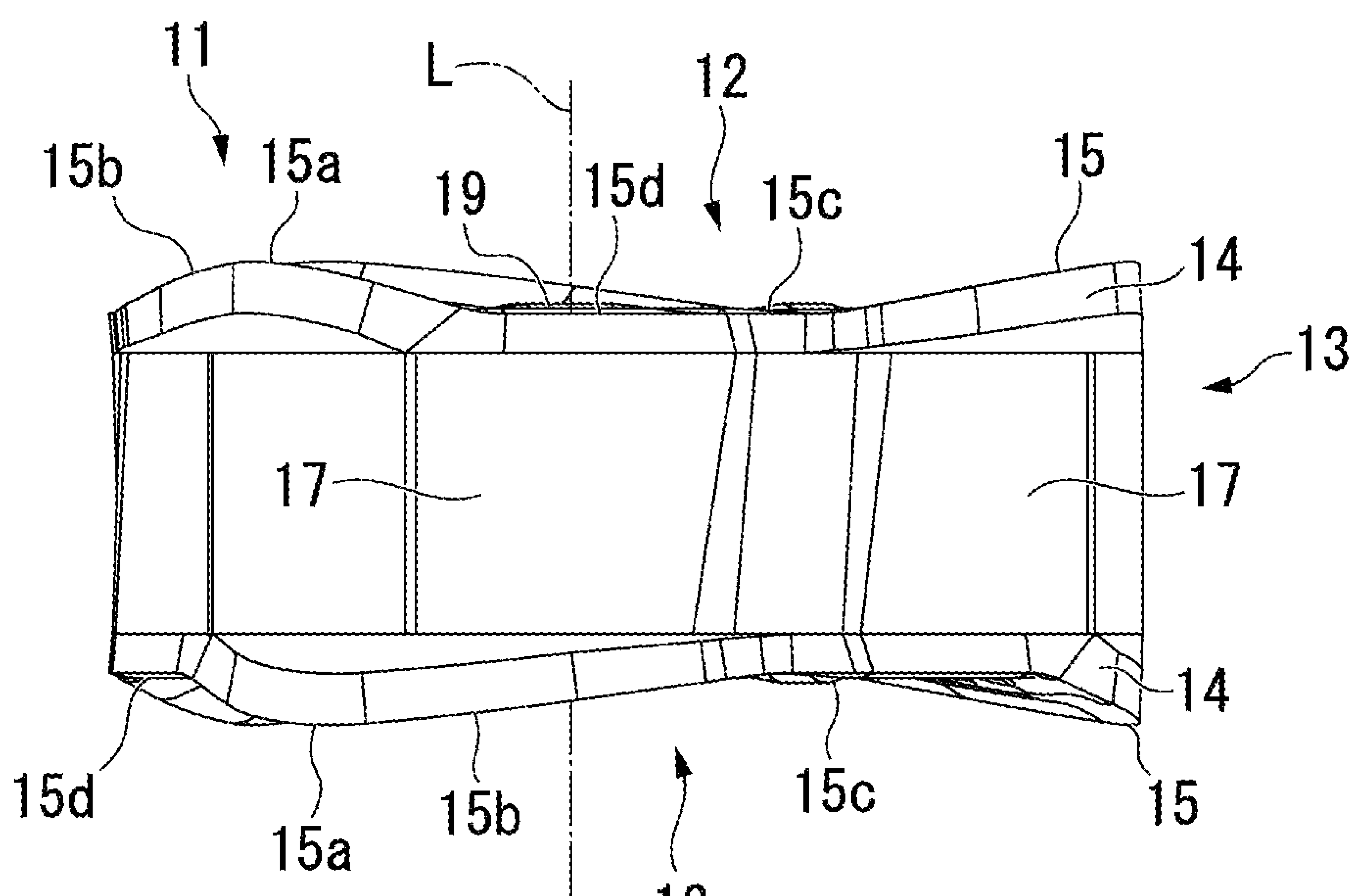

11
12
12a
12b
15
18
18
L
Y
Y
15d
19
V
Z
16
X
18a
18
15a
18
20a
20b
12b
20c
Z
X
13
15d
15c
15b
W

FIG. 34


11
L
12
15b
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13
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17
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15d
15a
15b
15c
15
12

FIG. 35

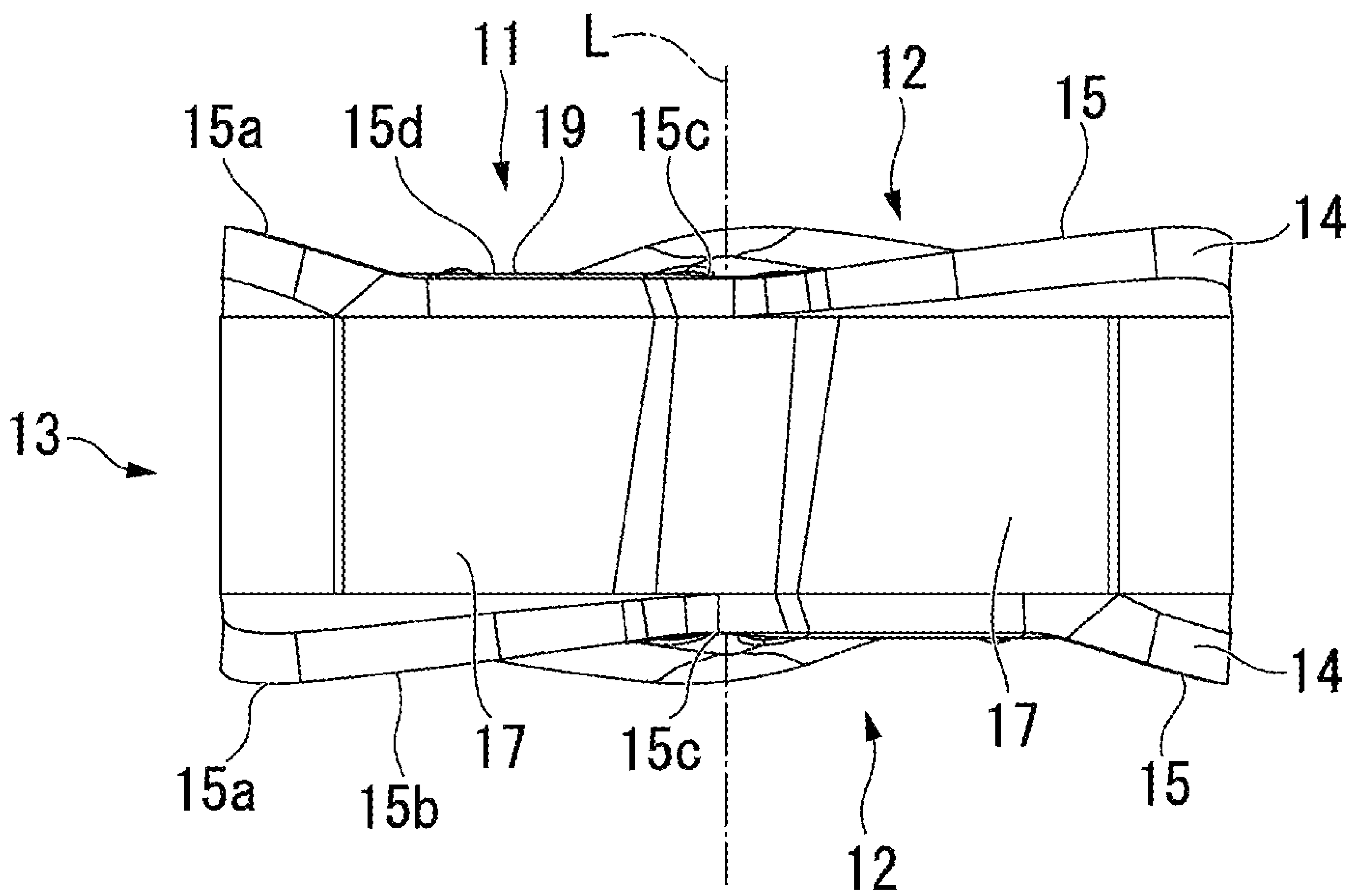

11
L
12
15a
15d
19
15c
15
14
13
17
17
14
15a
15b
15c
15
12

FIG. 36

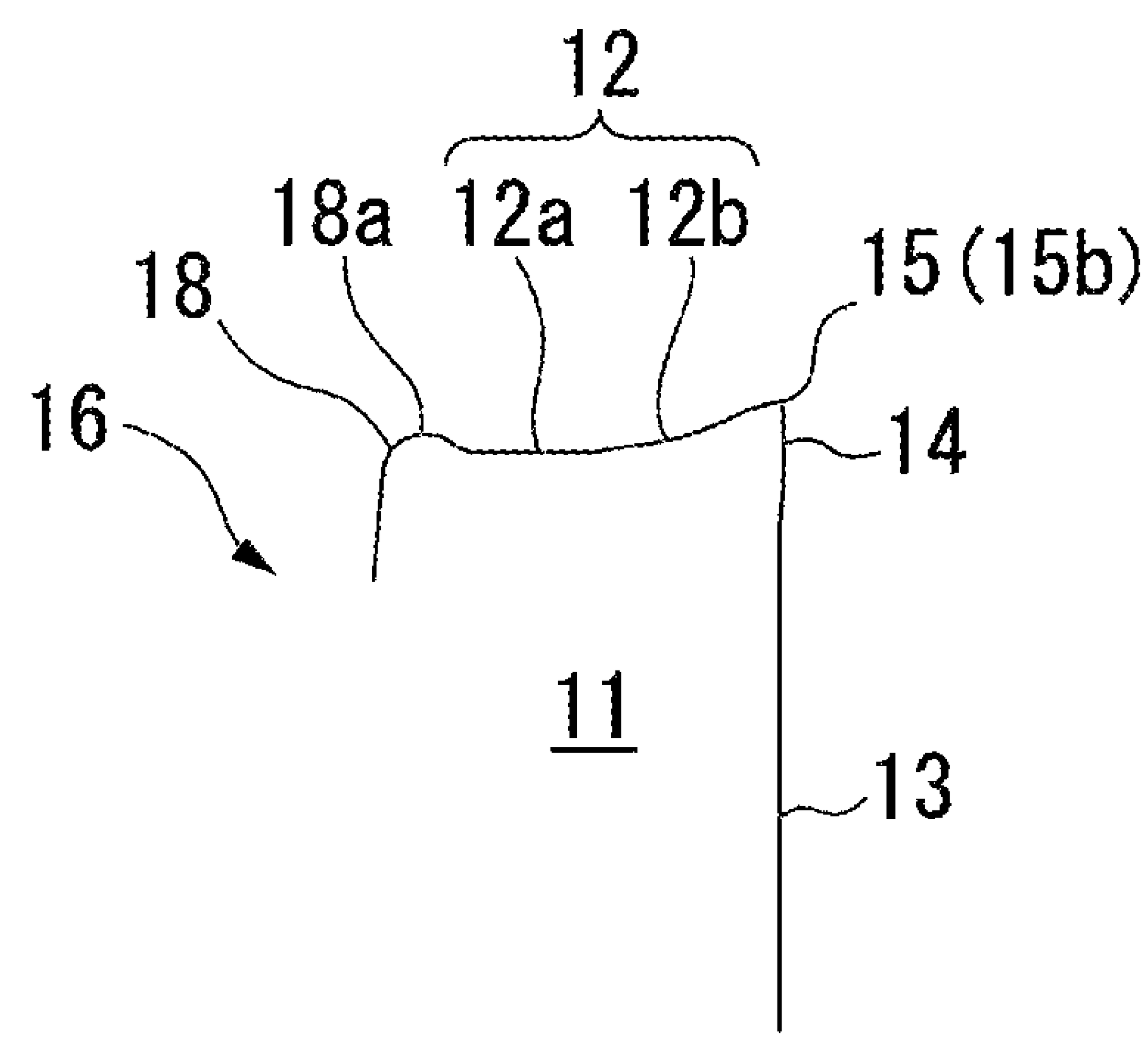

12
18a
12a
12b
18
15 (15b)
16
14
11
13

FIG. 37

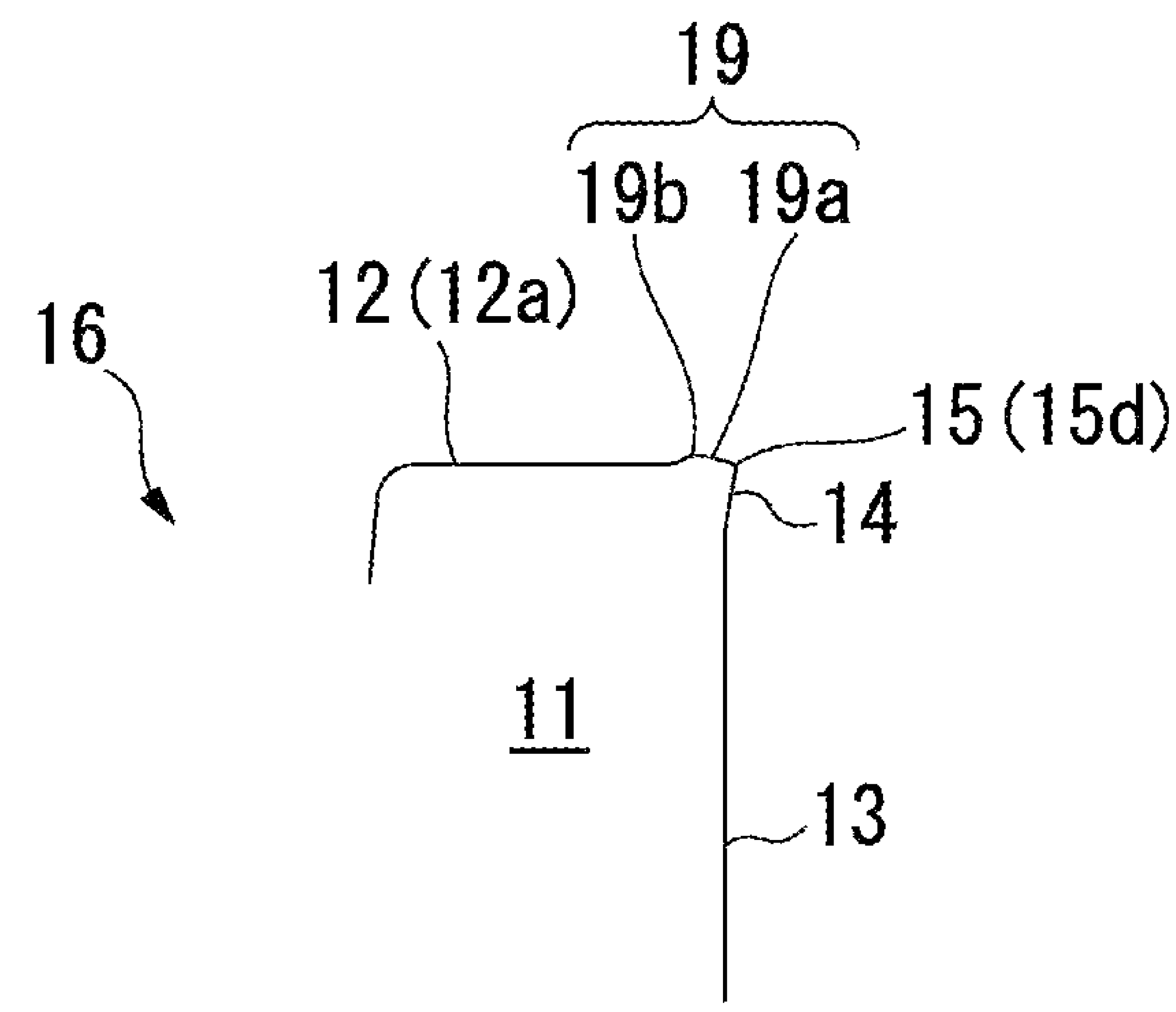

19
19b 19a
12 (12a)
16
15 (15d)
14
11
13

FIG. 38

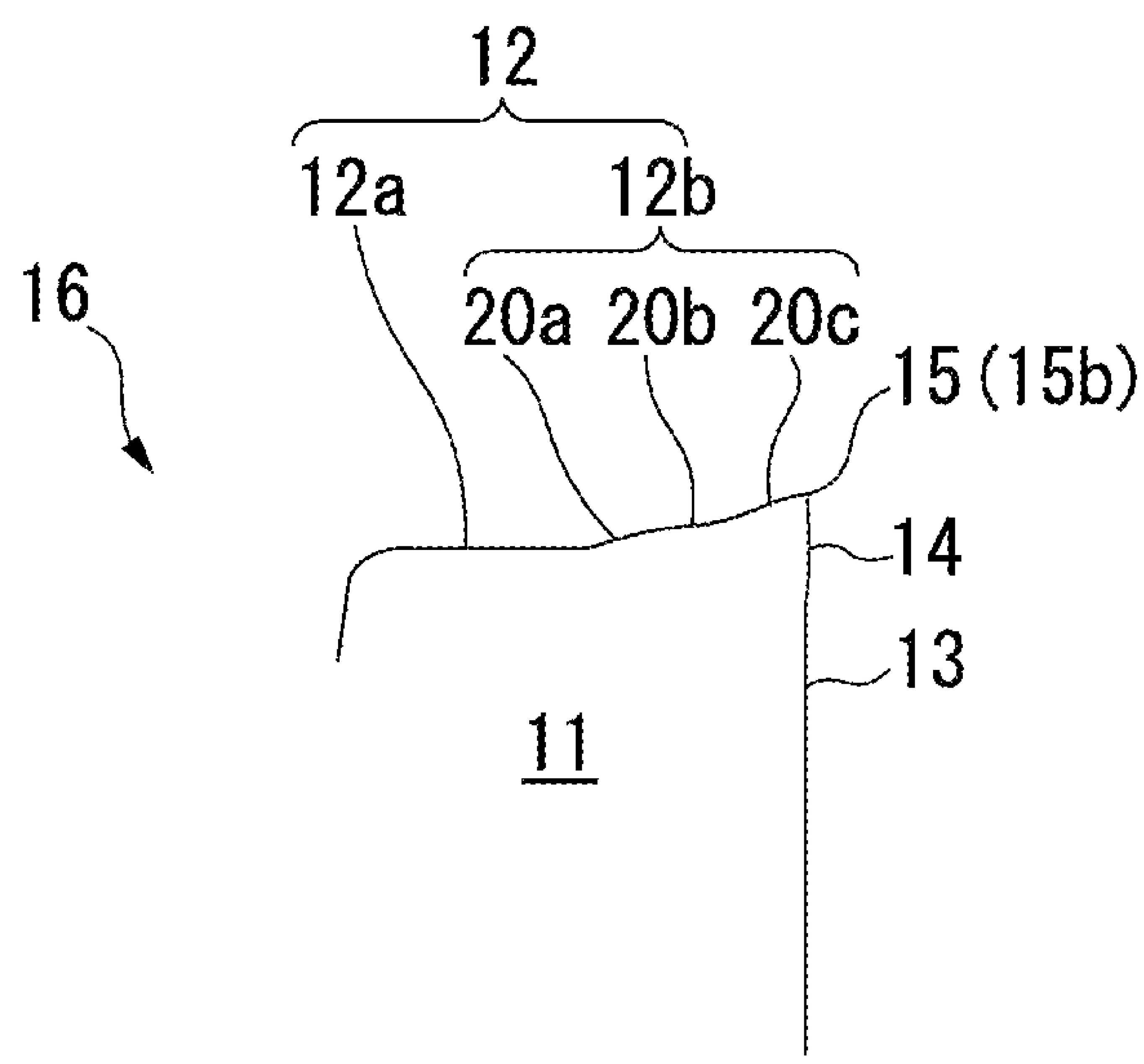

12
12a
12b
20a 20b 20c
16
15 (15b)
14
13
11

FIG. 39

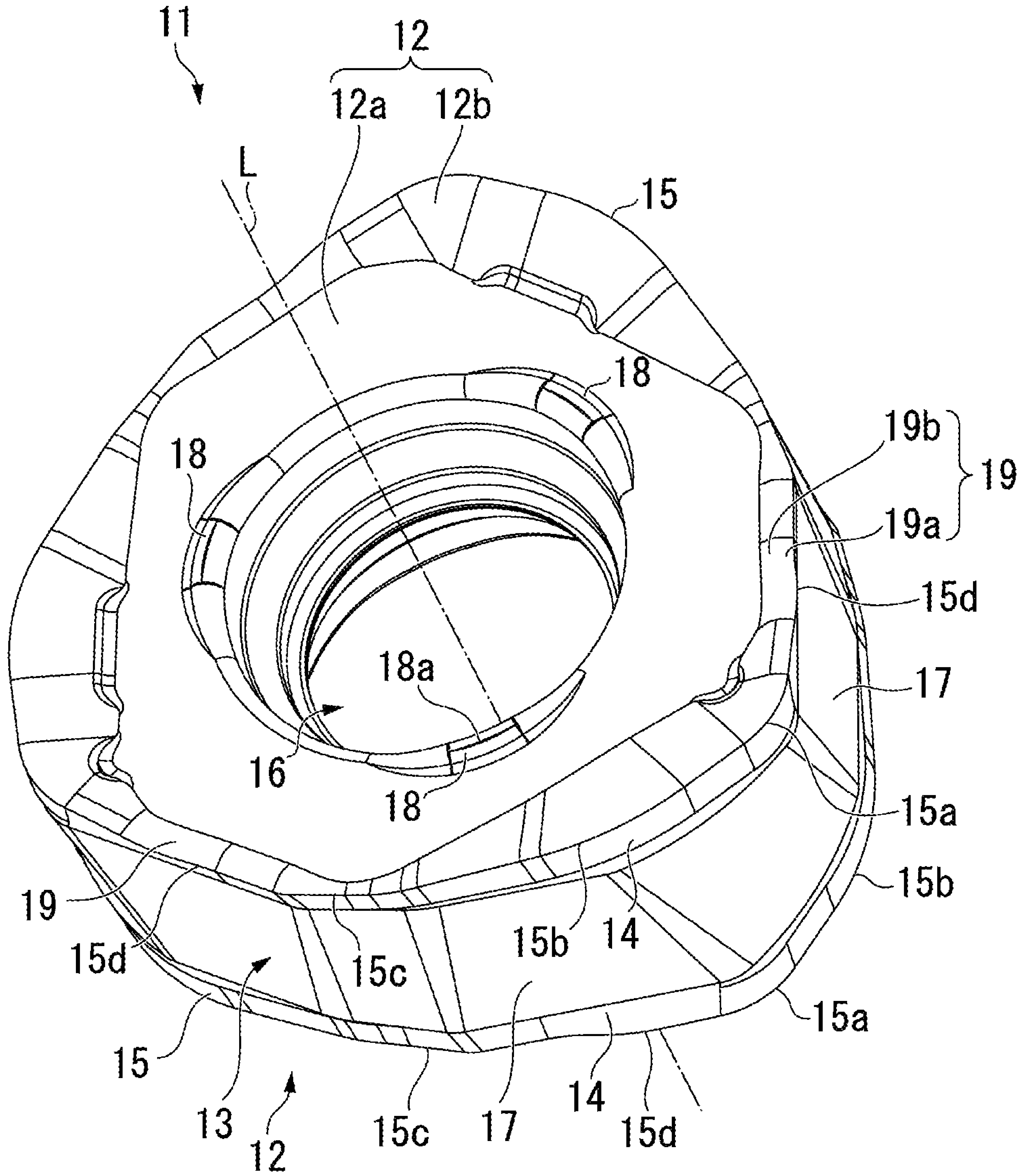

11
12
12a
12b
L
15
18
19b
19
19a
15d
17
18a
16
15a
15b
19
15d
15c
15b
14
15a
15
13
12
15c
17
14
15d

FIG. 40

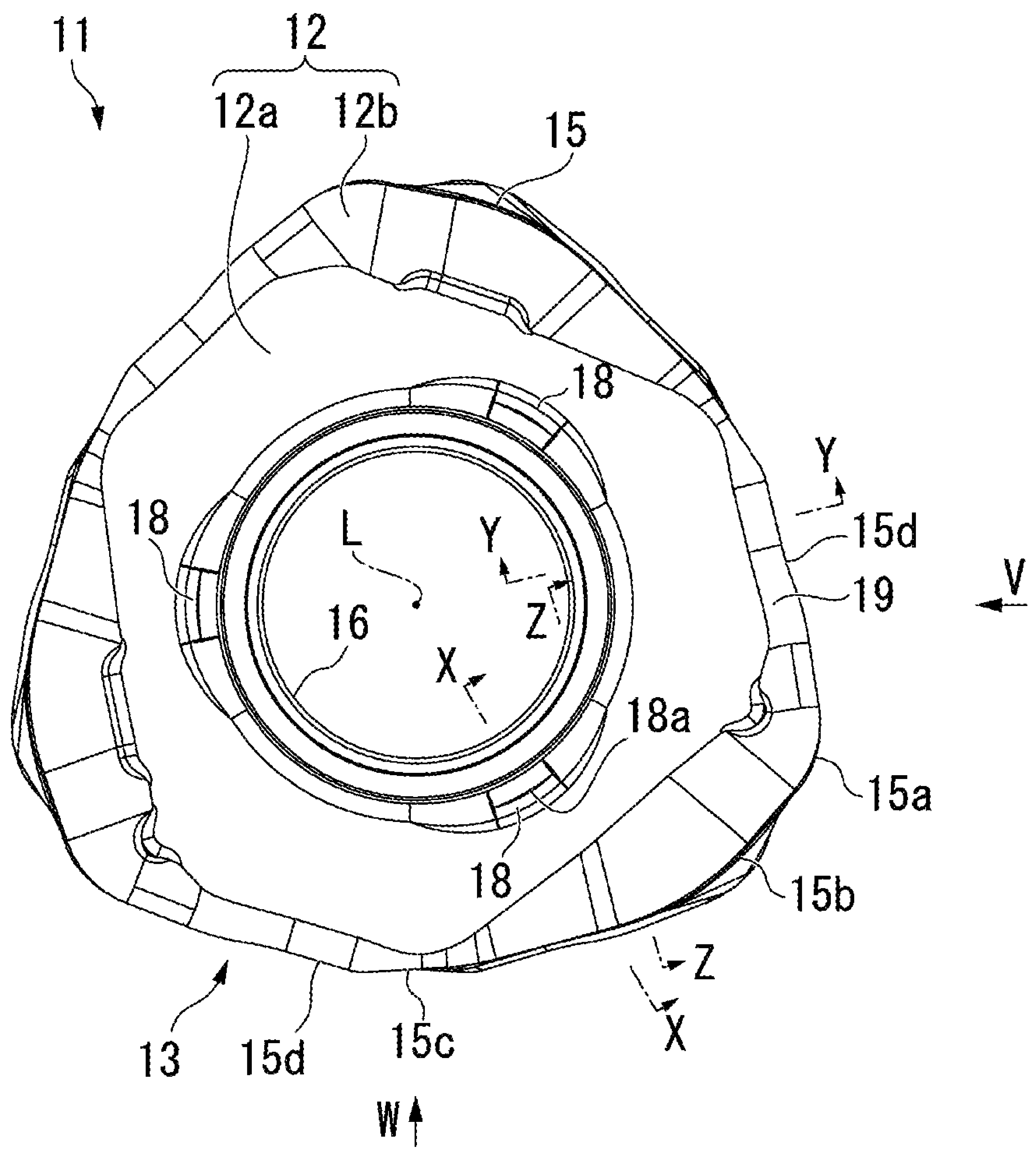

11
12
12a
12b
15
18
18
L
Y
Y
15d
V
19
16
Z
X
18a
15a
18
15b
Z
X
13
15d
15c
W

FIG. 41

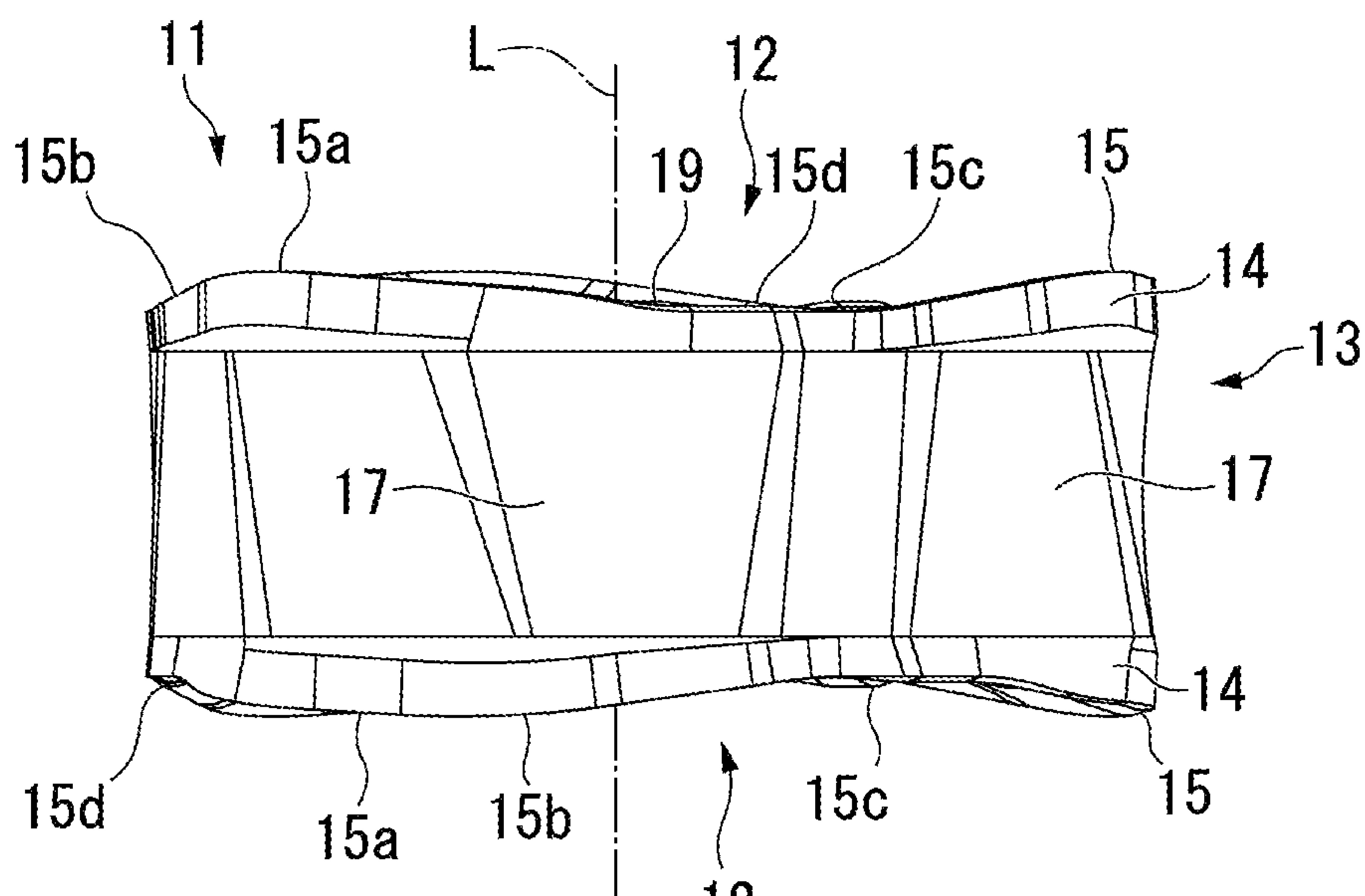

11
L
12
15b
15a
19
15d
15c
15
14
13
17
17
14
15d
15a
15b
15c
15
12

FIG. 42

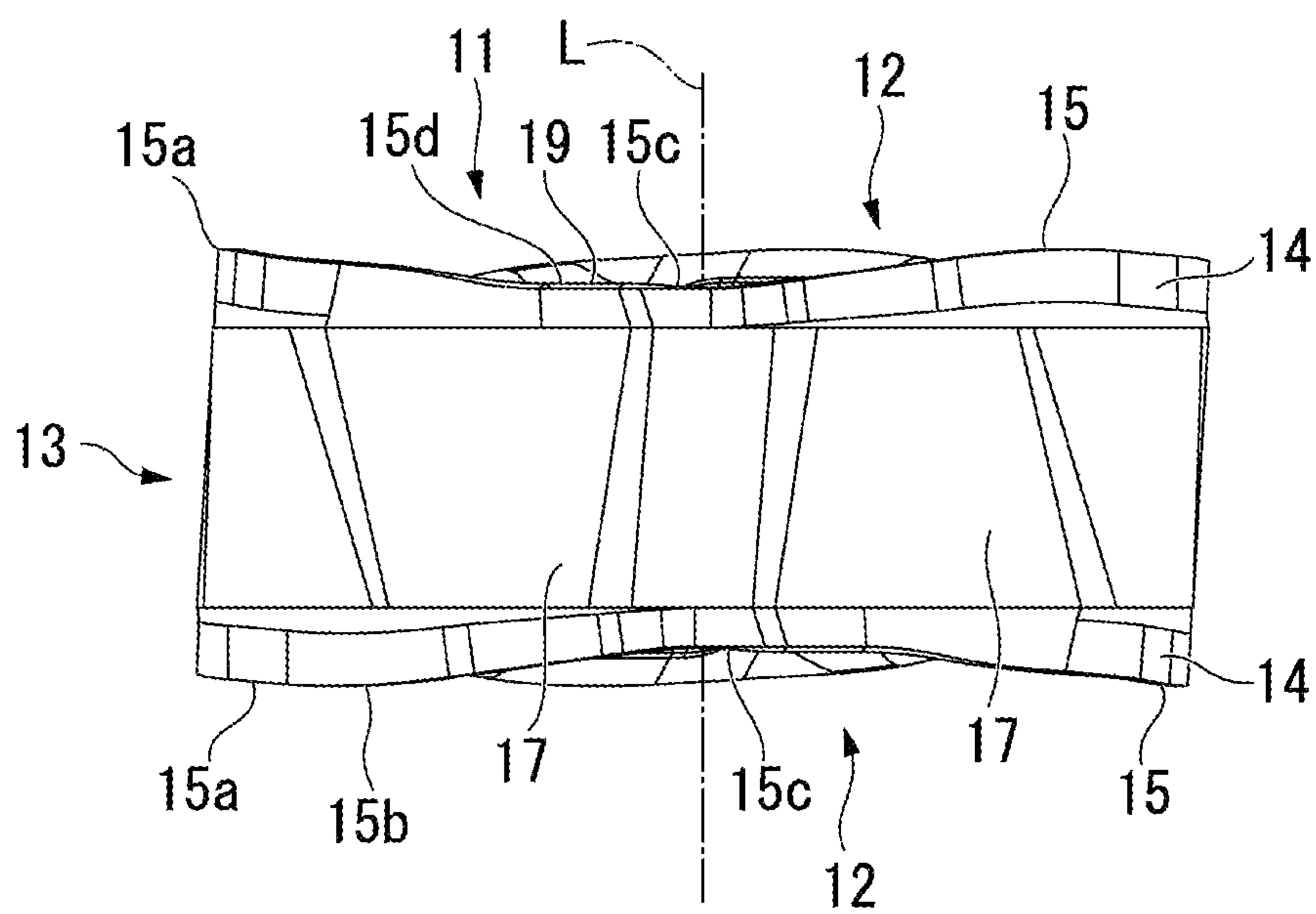

11
L
12
15
15a
15d
19
15c
14
13
17
17
14
15a
15b
15c
15
12

FIG. 43

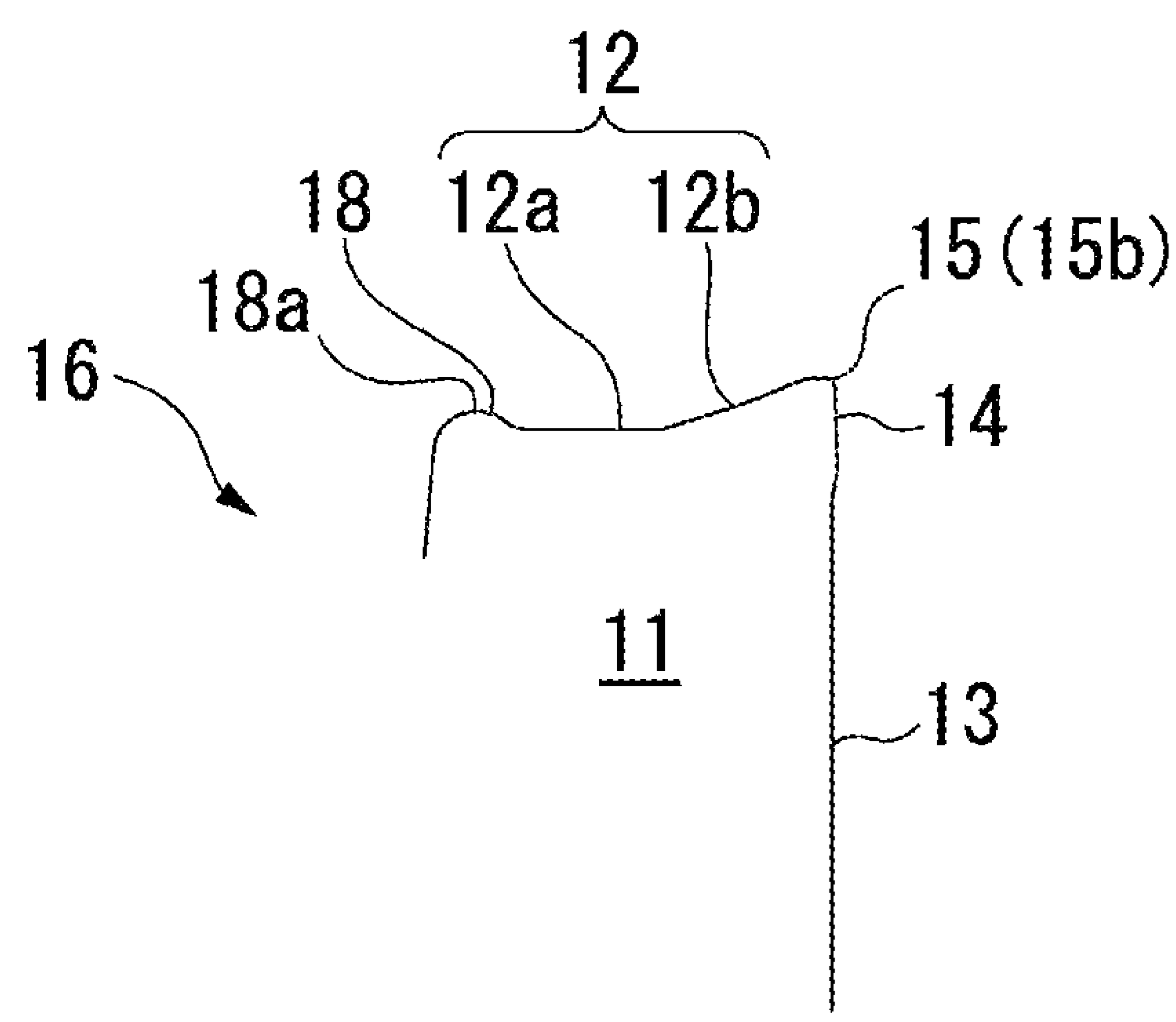

12
18
12a
12b
15 (15b)
18a
16
14
11
13

FIG. 44

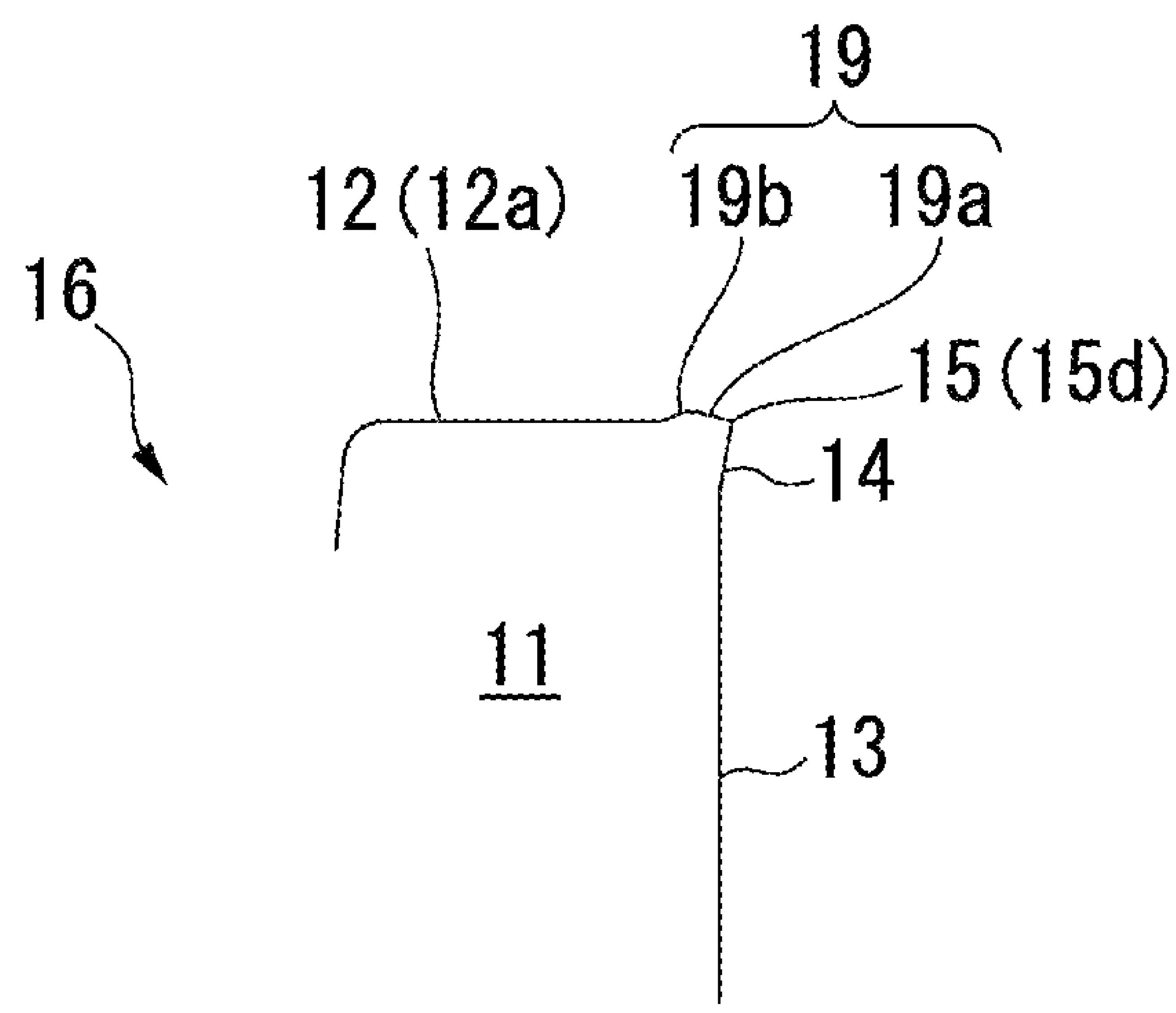
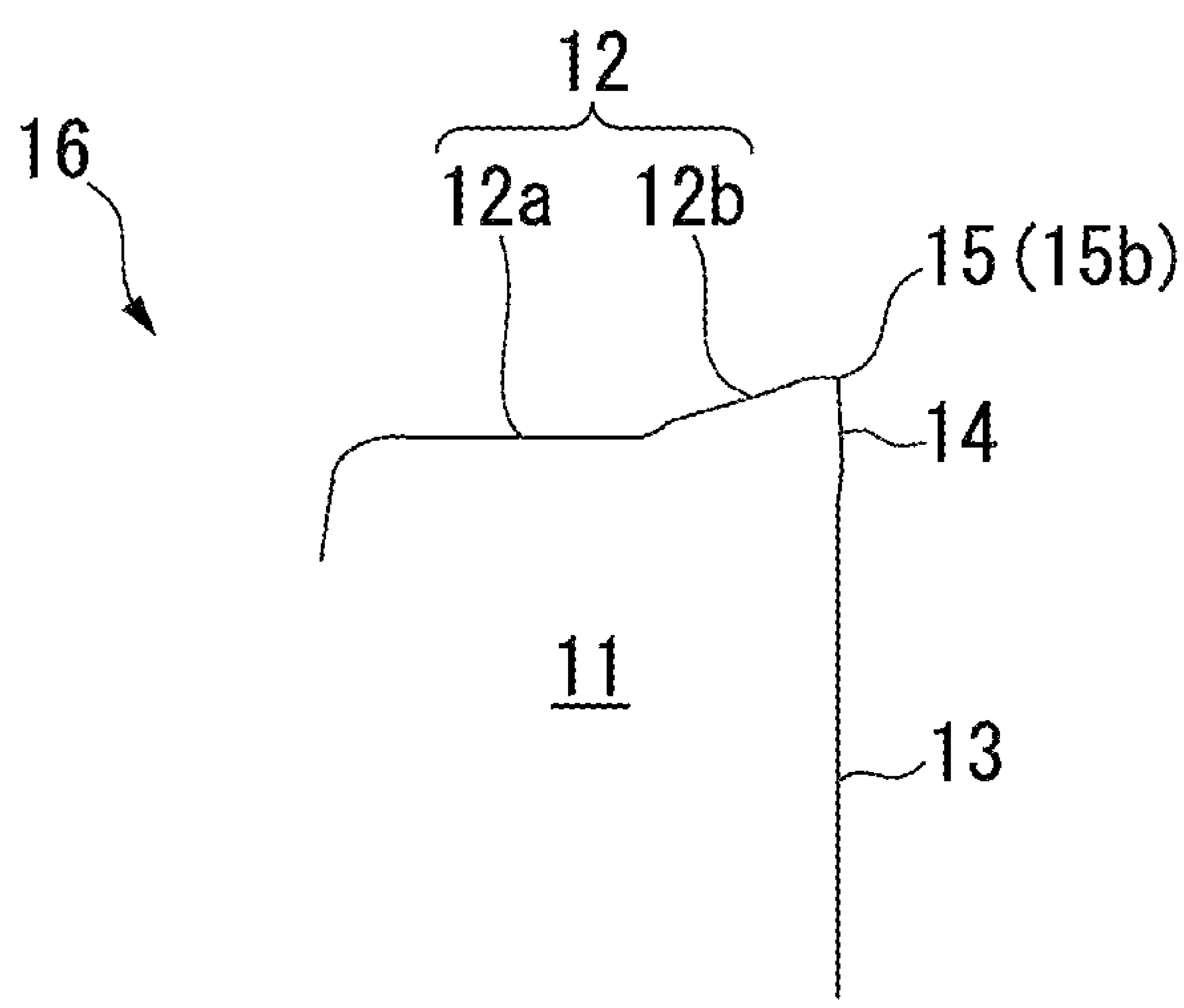


FIG. 45



CUTTING INSERT AND CUTTING EDGE REPLACEMENT TYPE CUTTING TOOL

TECHNICAL FIELD

The present invention relates to a cutting insert that is detachably mounted on an indexable cutting tool such as an indexable end mill, and an indexable cutting tool on which such a cutting insert is detachably mounted.

Priority is claimed on Japanese Patent Application No. 2018-110398, filed Jun. 8, 2018, the content of which is incorporated herein by reference.

BACKGROUND ART

For example, Patent Document 1 discloses, as a cutting insert and an indexable cutting tool, a cutting insert having a triangular plate shape in which an insert main body has two triangular surfaces each having a substantially triangular shape with three corners, and an indexable cutting tool in which the cutting insert is detachably mounted on an insert mounting seat by a clamp screw which is inserted into a mounting hole formed to penetrate the insert main body, wherein one triangular surface of the cutting insert is caused to serve as a rake face and to face in a tool rotation direction, a corner edge formed at one corner of the one triangular surface is caused to face an outer periphery side of a tool main body, a major cutting edge extending from a first end of the one corner edge is caused to face a tip end outer periphery side of the tool main body, and a minor cutting edge (a wiper edge) extending from a first end of the major cutting edge is located substantially on a plane perpendicular to a rotational axis of the tool main body.

In such a cutting insert, due to the major cutting edge that faces a tip end side of the tool main body and goes toward a posterior end side at a gentle angle with respect to the plane perpendicular to the rotational axis as it goes toward the outer periphery side of the tool main body, a thin chip is generated in the major cutting edge on an inner periphery side of the tool main body or in the above-described wiper edge, and thus it is possible to suppress an increase in cutting resistance even if the tool main body is fed at a high feed amount. Therefore, an efficient cutting operation can be performed in the processing of a mold or the like. Further, Patent Document 1 discloses that in a case in which a cutting amount in a Z-axis direction is set to be large in inclination cutting operation, a second minor cutting edge connected to a first minor cutting edge also acts as a cutting edge.

CITATION LIST

Patent Literature

[Patent Document 1]
Japanese Patent No. 5983901

SUMMARY OF INVENTION

Technical Problem

Meanwhile, in high feeding processing or a high cutting operation by the indexable cutting tool on which such a cutting insert mounted, it is required to secure a good chip discharging property. Particularly, in a case in which the inclination cutting operation such as engraving a pocket on a work material such as a mold as described in Patent Document 1 is performed, if the outflow direction of the chip

is not controlled, the chip is easily caught between the minor cutting edge (the second minor cutting edge) extending from the second end of the one corner edge facing the tip end side of the tool main body toward the posterior end side of the tool main body and an inner wall surface of the pocket as a depth of the pocket increases, and a fracture may be generated in the minor cutting edge, which may make it impossible to rotate the insert main body around the mounting hole and to remount it for use.

Here, it is known that in such a cutting insert, a chip breaker having a protrusion shape or the like is formed on the rake face, and the chip is brought into sliding contact with the chip breaker, and thus resistance is given to the chip and the outflow direction of the chip is controlled. However, as described in Patent Document 1, the insert main body has two triangular surfaces and is formed in a front-back inversion symmetrical shape, and after the cutting edge of one triangular surface is used, the insert main body is front-back inverted and remounted. Therefore, in a double-sided cutting insert that is configured to use the cutting edge of the other triangular surface, if the chip breaker is formed on the rake face unnecessarily, an area of close attachment between a boss surface of the insert main body which is a plane perpendicular to an insert center line passing through a center of the mounting hole and a bottom surface of the insert mounting seat of the tool main body which faces in the tool rotational direction becomes small in general, which may impair mounting stability of the cutting insert.

The present invention has been made in view of these circumstances, and an object of the present invention is to provide a cutting insert in which a fracture of a cutting edge due to a chip being caught can be prevented without impairing mounting stability of the cutting insert even if high feeding processing, a high cutting operation, or an engraving operation of a pocket is performed, and an indexable cutting tool on which such a cutting insert is detachably mounted.

Solution to Problem

To solve the above-described problems and achieve such an object, a cutting insert of the present invention includes: a polygonal plate-shaped insert main body that includes: two polygonal surfaces which have a polygonal shape and of which one serves as a rake face and the other serves as a seating surface; a side surface which is arranged around the two polygonal surfaces and in which a flank face intersecting with the rake face of the polygonal surfaces is formed; and a cutting edge which is formed on an intersecting ridgeline between the rake face and the flank face, wherein the insert main body has a mounting hole that penetrates the insert main body centered on an insert center line passing through centers of the two polygonal surfaces, has a rotationally symmetrical shape with respect to the insert center line, and has a front-back inversion symmetrical shape with respect to the two polygonal surfaces, wherein the cutting edge includes at least a corner edge located at a corner of the polygonal surface and a major cutting edge extending from a first end of the corner edge, and wherein, in an opening of the mounting hole in the two polygonal surfaces, a plurality of protrusions protruding with respect to a boss surface formed on the polygonal surface around the opening of the mounting hole are formed at intervals in a peripheral direction in an inner periphery side region of the major cutting edge.

An indexable cutting tool of the present invention is an indexable cutting tool in which the cutting insert configured in this manner is detachably mounted on an insert mounting seat formed on an outer periphery of a tip end portion of a tool main body which is rotated around an axis in such a manner that a clamp screw which is inserted into the mounting hole is screwed into a screw hole formed in a bottom surface of the insert mounting seat which faces in a tool rotation direction, wherein, in the insert main body, one polygonal surface of the two polygonal surfaces is caused to serve as a rake face and to face in the tool rotation direction, and the boss surface of the other polygonal surface is closely attached to the bottom surface of the insert mounting seat, wherein the insert main body is mounted in such a manner that the one corner edge of the one polygonal surface faces an outer periphery side of the tool main body and the one major cutting edge extending from a first end of the one corner edge is caused to face a tip end side of the tool main body, and wherein accommodation recesses for accommodating the protrusions of the other polygonal surface are formed around an opening of the screw hole in the bottom surface of the insert mounting seat.

In the cutting insert and the indexable cutting tool having the above-described configuration, the plurality of protrusions protruding with respect to the boss surface formed on the polygonal surface around the opening of the mounting hole are formed on the opening of the mounting hole in the two polygonal surfaces of the insert main body at intervals in the peripheral direction in the inner periphery side region of the major cutting edge, and thus the protrusions act as chip breakers and the outflow direction can be controlled. In particular, since the protrusions are formed at intervals in the peripheral direction, the chip brought into sliding contact with the protrusions can be guided to a portion between the protrusions, and the outflow direction of the chip can be controlled.

Meanwhile, since the protrusions are formed at intervals in the peripheral direction in this manner, the boss surface can be closely attached to the bottom surface of the insert mounting seat of the tool main body up to a space between the protrusions in the opening of the mounting hole and mounting stability of the cutting insert can be secured. Moreover, since the protrusions are formed in the opening of the mounting hole on the innermost periphery side of the boss surface, the area of close attachment to the bottom surface of the insert mounting seat in the outer peripheral portion of the boss surface does not become small, and thus it is possible to more reliably stabilize the mounting of the cutting insert.

Preferably, in the protrusions, furthest protruding portions which protrude furthest from the boss surface extend with a predetermined length around the opening of the mounting hole. Since the furthest protruding portions of the protrusions which protrude furthest from the boss surface extend around the opening of the mounting hole with a predetermined length, it is possible to reliably bring the chip into sliding contact with the protrusions and to control the outflow direction, and it is possible to prevent wear of the protrusions due to sliding contact of the chip.

Preferably, in a case in which the furthest protruding portions extend with a predetermined length, for example, the length of each furthest protruding portion in the peripheral direction of the opening portion of the mounting hole is in a range of 5% to 8% with respect to a periphery length of the entire periphery of the opening of the mounting hole.

To control the outflow direction of the chip, the furthest protruding portions preferably extend at a predetermined protruding height, but in some cases, wavy protrusions having a plurality of protruding ends in which the furthest protruding portions and portions slightly lower than the furthest protruding portions are continuous in the peripheral direction is possible.

Preferably, in the protrusions, when seen in a direction facing the polygonal surface, furthest protruding portions which protrude furthest from the boss surface are similarly located between a straight line connecting the first end of the corner edge and the insert center line to each other and a straight line connecting a first end of the major cutting edge on a side opposite to the first end of the corner edge and the insert center line to each other. Accordingly, it is also possible to reliably bring the chip that is generated by the major cutting edge and flows out to the inner periphery side of the rake face during high feeding processing or a high cutting operation into sliding contact with the protrusions and to control the outflow direction, and it is possible to prevent the chip from coming into sliding contact with the clamp screw and to prevent wear of the clamp screw.

Preferably, in a case in which the insert main body has a triangular plate shape in which each of the two polygonal surfaces has three corners, when seen in the direction facing the polygonal surface, the furthest protruding portions are located in an angle range of 15° to 40° centered on the insert center line from the straight line connecting the first end of the major cutting edge on the side opposite to the first end of the corner edge and the insert center line to each other toward the corner edge side. In a case in which the insert main body is mounted on the tool main body of the indexable cutting tool, such an angle range is a portion which is located on the inner periphery side of the tool main body in the major cutting edge and at which a thin chip is generated, and the furthest protruding portions of the protrusions are disposed in the inner periphery side region of the major cutting edge in such a portion, and thus the outflow direction of the entire chip can be effectively controlled and the cutting resistance can be further reduced. Further, it is possible to reliably prevent wear of the protrusions due to the thick chip.

Preferably, in a case in which the cutting edge further includes a minor cutting edge extending from the second end of the corner edge toward the other cutting edge adjacent to the second end side of the corner edge, the minor cutting edge is formed to extend to a region of the boss surface at least on a side opposite to the corner edge, and in a portion extending to the region of the boss surface, the minor cutting edge is formed on an intersecting ridgeline between an inclined face that goes toward the polygonal surface side opposite to the subject polygonal surface as it goes toward an outer periphery side of the subject polygonal surface and the flank face.

Therefore, at the portion which extends to the region of the boss surface, it is possible to secure a large edge angle of the minor cutting edge and to improve a cutting edge strength. Thus, in a case in which the engraving operation of the pocket is performed on the work material such as a mold, for example, in a state in which the outflow direction of the chip is not sufficiently controlled, even if the chip flows from the one corner edge toward the minor cutting edge side extending to the posterior end side of the tool main body and is caught between the inner wall surface of the pocket and the minor cutting edge, it is possible to prevent a fracture from being generated in the minor cutting edge.

In this case, in the outer peripheral portion of the polygonal surface, the protruding ridge portion that protrudes with respect to the boss surface is formed along the minor cutting edge of a portion extending to the region of the boss surface, and the inclined face is formed on an outer peripheral surface of the protruding ridge portion facing the outer periphery side of the polygonal surface. Therefore, even if the chip flows toward the minor cutting edge side in a case of the engraving operation as described above, before the chip is caught between the minor cutting edge and the inner wall surface of the pocket, the chip comes into sliding contact with an inner peripheral surface of the protruding ridge portion that protrudes from the boss surface, which faces the inner periphery side and receives resistance, and thus the chip is curled. Therefore, it is possible to prevent the chip from being caught. Here, the inclined face may be formed in a chamfered shape that faces the opposite polygonal surface side as it goes from the boss surface toward the outer periphery side of the polygonal surface.

Meanwhile, in a case in which the boss surface is a plane perpendicular to the insert center line as described above, an inclined portion that is inclined to protrude in a direction of the insert center line as it goes from the boss surface toward the cutting edge side is formed on the polygonal surface. Therefore, it is possible to increase a rake angle of the cutting edge which is formed on the intersecting ridgeline between the inclined portion and the flank face to a regular angle side to ensure sharp cutting quality, and thus it is possible to reduce the cutting resistance at the time of the high feeding processing or the high cutting operation.

Further, in a case in which the inclined portion is formed in this manner, in a cross section orthogonal to the major cutting edge, the inclined portion has a first steeply inclined portion that protrudes in the direction of the insert center line as it goes from the boss surface toward the major cutting edge side, a gently inclined portion that is continuous with the first steeply inclined portion on the major cutting edge side and protrudes in the direction of the insert center line at a gradient gentler than the first steeply inclined portion as it goes toward the major cutting edge side, and a second steeply inclined portion that is continuous with the gently inclined portion on the major cutting edge side and protrudes in the direction of the insert center line at a gradient steeper than the gently inclined portion as it goes toward the major cutting edge side. Therefore, when the chip flows from the second steeply inclined portion to the gently inclined portion, or when the chip flows from the gently inclined portion to the first steeply inclined portion, it is possible to give resistance to the chip, and particularly it is possible to improve a processing property of the chip at the time of the high feeding processing.

Advantageous Effects of Invention

As described above, according to the present invention, the fracture of the cutting edge due to the chip being caught can be prevented without impairing the mounting stability of the cutting insert on the insert mounting seat even if the high feeding processing, the high cutting operation, or the engraving operation of the pocket is performed, and stable cutting can be performed over a long period of time.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective view showing a first embodiment of a cutting insert of the present invention.

FIG. **2** is a plan view of the embodiment shown in FIG. **1** in a direction of an insert center line.

FIG. **3** is a side view in a direction of arrow V in FIG. **2**.

FIG. **4** is a side view in a direction of arrow W in FIG. **2**.

FIG. **5** is a sectional view along line XX in FIG. **2**.

FIG. **6** is a sectional view along line YY in FIG. **2**.

FIG. **7** is a sectional view along line ZZ in FIG. **2**.

FIG. **8** is a diagram showing a protruding height from a boss surface around an opening of a mounting hole and a cutting edge in a cross section along an insert center line of the embodiment shown in FIG. **1**.

FIG. **9** is a perspective view of a tool main body in an embodiment of an indexable cutting tool of the present invention on which the cutting insert of the embodiment shown in FIG. **1** is to be detachably mounted.

FIG. **10** is a bottom view of the tool main body shown in FIG. **9**.

FIG. **11** is a plan view of the tool main body shown in FIG. **9**.

FIG. **12** is a side view in a direction of arrow W in FIG. **10**.

FIG. **13** is an enlarged view of a portion A in FIG. **12**.

FIG. **14** is a side view in a direction of arrow X in FIG. **10**.

FIG. **15** is a side view in a direction of arrow Yin FIG. **10**.

FIG. **16** is a side view in a direction of arrow Z in FIG. **10**.

FIG. **17** is a perspective view showing the embodiment of the indexable cutting tool of the present invention in which the cutting insert of the embodiment shown in FIG. **1** has been detachably mounted on the tool main body shown in FIG. **9**.

FIG. **18** is a bottom view of the indexable cutting tool shown in FIG. **17**.

FIG. **19** is a plan view of the indexable cutting tool shown in FIG. **17**.

FIG. **20** is a side view in a direction of arrow W in FIG. **18**.

FIG. **21** is an enlarged view of a portion A in FIG. **20**.

FIG. **22** is a side view in a direction of arrow X in FIG. **18**.

FIG. **23** is a side view in a direction of arrow Y in FIG. **18**.

FIG. **24** is a side view in a direction of arrow Z in FIG. **18**.

FIG. **25** is a perspective view showing a second embodiment of a cutting insert of the present invention.

FIG. **26** is a plan view of the embodiment shown in FIG. **25** in a direction of an insert center line.

FIG. **27** is a side view in a direction of arrow V in FIG. **26**.

FIG. **28** is a side view in a direction of arrow W in FIG. **26**.

FIG. **29** is a sectional view along line XX in FIG. **26**.

FIG. **30** is a sectional view along line YY in FIG. **26**.

FIG. **31** is a sectional view along line ZZ in FIG. **26**.

FIG. **32** is a perspective view showing a third embodiment of a cutting insert of the present invention.

FIG. **33** is a plan view of the embodiment shown in FIG. **32** in a direction of an insert center line.

FIG. **34** is a side view in a direction of arrow V in FIG. **33**.

FIG. **35** is a side view in a direction of arrow W in FIG. **33**.

FIG. **36** is a sectional view along line XX in FIG. **33**.

FIG. **37** is a sectional view along line YY in FIG. **33**.

FIG. **38** is a sectional view along line ZZ in FIG. **33**.

FIG. **39** is a perspective view showing a fourth embodiment of a cutting insert of the present invention.

FIG. **40** is a plan view of the embodiment shown in FIG. **39** in a direction of an insert center line.

FIG. **41** is a side view in a direction of arrow V in FIG. **40**.

FIG. **42** is a side view in a direction of arrow W in FIG. **40**.

FIG. **43** is a sectional view along line XX in FIG. **40**.

FIG. **44** is a sectional view along line YY in FIG. **40**.

FIG. **45** is a sectional view along line ZZ in FIG. **40**.

DESCRIPTION OF EMBODIMENTS

FIGS. **1** to **8** show a first embodiment of a cutting insert of the present invention, FIGS. **9** to **16** show a tool main body in an embodiment of an indexable cutting tool of the present invention on which the cutting insert of the embodiment is to be detachably mounted, and FIGS. **17** to **24** show the embodiment of the indexable cutting tool of the present invention in which the cutting insert of the embodiment has been detachably mounted on the tool main body.

The cutting insert of the present embodiment includes a polygonal plate-shaped insert main body **11** formed of a hard material such as cemented carbide, and the insert main body **11** has a triangular plate shape in which each of two polygonal surfaces **12** has three corners as shown in FIG. **2**, has a rotationally symmetrical shape with respect to an insert center line L passing through centers of the two polygonal surfaces **12** when seen in a direction facing the polygonal surfaces **12**, and has a front-back inversion symmetrical shape with respect to the two polygonal surfaces **12**.

When the two polygonal surfaces **12** are mounted on the tool main body **21** of the indexable cutting tool as shown in FIG. **17**, one of the polygonal surfaces **12** serves as a rake face and the other of the polygonal surfaces **12** serves as a seating surface for an insert mounting seat **22** formed on the tool main body **21**. A flank face **14** that intersects with the rake surface of the two polygonal surfaces **12** is formed on a side surface **13** of the insert main body **11** arranged around the two polygonal surfaces **12**, and a cutting edge **15** is formed on an intersecting ridgeline between the rake face (the polygonal surface **12**) and the flank face **14**. In addition, a mounting hole **16** which is for mounting the insert main body **11** on the insert mounting seat **22** and which has a circular cross section centered on the insert center line L is provided in centers of the two polygonal surfaces **12** such that the mounting hole penetrates the insert main body **11** in a direction of the insert center line L to open.

When seen in the direction of the insert center line L, the cutting edge **15** includes a corner edge **15***a* which is disposed at three corners of the polygonal surface **12** and which has a convex curved shape such as an arc, a major cutting edge **15***b* which extends from a first end (an end portion on a side in a clockwise direction centered on the insert center line L in FIG. **2**) of the corner edge **15***a* in contact with the corner edge **15***a* and which has a straight line shape or a convex curve shape of which a radius of curvature is larger than that of a convex curve formed by the corner edge **15***a*, and a wiper edge **15***c* which extends in a direction intersecting with the major cutting edge **15***b* at an obtuse angle in a first end of the major cutting edge **15***b* and which has a straight line shape or a convex curve shape of which a radius of curvature is larger than that of a convex curve formed by the major cutting edge **15***b*.

The cutting edge **15** further includes a minor cutting edge **15***d* which extends from the second end of the corner edge **15***a* in contact with the corner edge **15***a* and which has a straight line shape when seen in the direction of the insert center line L. The minor cutting edge **15***d* extends in a direction intersecting with the wiper edge **15***c* of the other of the cutting edges **15** adjacent to the second end side (a side in a counterclockwise direction centered on the insert center line L in FIG. **2**) of the one cutting edge **15** at an obtuse angle.

In boundaries between the corner edge **15***a*, the major cutting edge **15***b*, the wiper edge **15***c*, and the minor cutting edge **15***d*, a boundary point between the cutting edges in a case in which two curves having different radii of curvature are connected to each other is set as a center point when the radius of curvature changes by 10% or more. With the insert center line L as a reference, the radii of curvature at this time are obtained by measuring positions where a straight line orthogonal to the insert center line intersects with the cutting edge at intervals of 1 to 5 degrees. In a case in which a curve and a straight line are connected to each other, the boundary point between the cutting edges is set as a contact point between the curve and the straight line. The straight line at this time is a tangent to the curve. In a case in which two straight lines are connected to each other, the boundary point between the cutting edges is set as an intersection point between the two straight lines.

The flank face **14** is formed on each of edges of the side surface **13** of the insert main body **11** on the side of the two polygonal surfaces **12**, and in a cross section along the insert center line L, a plurality of insert constraining surfaces **17** extending in the direction of the center line L are formed between the flank faces **14** in directions intersecting with each other when seen in the direction of the insert center line L. In the present embodiment, the insert constraining surfaces **17** are flat surfaces parallel to the insert center line L and are formed inside the major cutting edge **15***b* and the minor cutting edge **15***d* in the direction of the insert center line L. Between the insert constraining surfaces **17** that are adjacent to each other, a portion which is located on the inside of the corner edge **15***a* in the direction of the insert center line Lis connected as a convex curved surface.

Further, in the polygonal surface **12** which serves as a rake face, a planar boss surface **12***a* perpendicular to the insert center line L is formed around an opening of the mounting hole **16**, and the mounting hole **16** opens on the boss surface **12***a*. Furthermore, an inclined portion **12***b* that is inclined to protrude in the direction of the insert center line L (outward from the insert main body in the direction of the insert center line L) as it goes from the boss surface **12***a* toward the cutting edge **15** is formed on the cutting edge **15** side in an outer periphery side of the polygonal surface **12** from the boss surface **12***a*.

In the present embodiment, the entire length of the corner edge **15***a* and the major cutting edge **15***b* of the cutting edge **15** and a portion of the minor cutting edge **15***d* which is in contact with the corner edge **15***a* are formed in the intersecting ridgeline between the inclined portion **12***b* and the flank face **14**. In the present embodiment, as shown in FIG. **7**, in a cross section orthogonal to the major cutting edge **15***b*, the inclined portion **12***b* is inclined to protrude in the direction of the insert center line L at a predetermined inclination as it goes from the boss surface **12***a* toward the major cutting edge **15***b* side, and has a positive land on the major cutting edge **15***b* side. Further, a portion of the minor cutting edge **15***d* on a side opposite to the corner edge **15***a* extends to a region of the boss surface **12***a*.

Here, the cutting edge **15** protrudes furthest from the boss surface **12***a* in the direction of the insert center line L at a periphery of the first end of the corner edge **15***a*, retracts in the direction of the insert center line L as it goes away from the first end of the corner edge **15***a* along the major cutting edge **15***b* and the minor cutting edge **15***d*, and retracts furthest in the direction of the insert center line L at a portion of the minor cutting edge **15***d* at which the region of the boss surface **12***a* is formed and a portion of the wiper edge **15***c*.

A plurality of protrusions **18** protruding with respect to the boss surface **12***a* along the insert center line L (outward from the insert main body in the direction of the insert center line L) are formed on the opening of the mounting hole **16** in the polygonal surface **12**, that is, the opening of the mounting hole **16** to the boss surface **12***a* at intervals in a peripheral direction in an inner periphery side region of the major cutting edge **15***b* of the polygonal surface **12** as shown in FIGS. **1** and **2**. The inner periphery side region of the major cutting edge **15***b* is a region on the polygonal surface **12** on the inside of the major cutting edge **15***b* toward the center of the polygonal surface **12** when seen in the direction facing the polygonal surface **12**, and is defined as a region interposed between a straight line M**1** connecting a first end of the major cutting edge (a first end portion of the major cutting edge **15***b*) and the center of the polygonal surface **12** to each other and a straight line M**2** connecting the second end of the major cutting edge **15***b* (a second end portion of the major cutting edge **15***b*) and the center of the polygonal surface **12** to each other. Being formed at intervals in the peripheral direction means that the plurality of protrusions **18** provided in a plurality of inner regions corresponding to a plurality of the major cutting edges **15***b* are provided at intervals. In the cross section orthogonal to the major cutting edge **15***b* as shown in FIG. **5**, the protrusions **18** rise while drawing a concave curve such as a concave arc which is in contact with the boss surface **12***a* as it goes toward the inner periphery side of the polygonal surface **12**, protrude in the direction of the insert center line L while drawing a convex curve such as a convex arc which is in contact with the concave curve and then retract, and are in contact with an inner periphery of the opening of the mounting hole **16**.

Here, a diagram A shown with white circles of FIG. **8** shows protruding heights of the opening of the mounting hole **16** from the boss surface **12***a* in the cross section along the insert center line L of the cutting insert of the present embodiment. As shown in FIG. **2**, a position of approximately ½ of the length of the wiper edge **15***c* of one cutting edge **15** is set to 0°, and a protruding height of the opening of the mounting hole **16** in the cross section at each position shifted by 5° each in the counterclockwise direction centered on the insert center line L in FIG. **2** is shown in the range of 120° up to a position of approximately ½ of the length of the wiper edge **15***c* of the other cutting edge **15** that intersects with the minor cutting edge **15***d* on the counterclockwise side.

As shown in the diagram A of FIG. **8**, in the peripheral direction of the opening of the mounting hole **16**, the protrusions **18** of the present embodiment are formed to gradually protrude from the boss surface **12***a* toward furthest protruding portions **18***a* having the furthest protruding height, extend with a predetermined length around the opening of the mounting hole **16** while maintaining the furthest protruding height that is predetermined, and then gradually retract in the direction of the insert center line L so that the protruding height becomes to the height of the boss surface **12***a*. However, the protrusions **18** may gradually protrude from the boss surface **12***a* and then gradually retract without having the predetermined protruding height and the predetermined length, or may have a wavy shape that has a plurality of protruding ends as shown in a diagram C with triangles of FIG. **8** in which they protrude from the boss surface **12***a*, retract with or without the predetermined protruding height and the predetermined length, and then protrude again.

Further, as also shown in the diagram A of FIG. **8**, in the present embodiment, in the protrusions **18**, the furthest protruding portions **18***a* that protrude furthest from the boss surface **12***a* are located within the inner periphery side region of the major cutting edge **15***b*. That is, when seen in the direction facing the polygonal surface **12**, as shown in FIG. **2**, the furthest protruding portions **18***a* of the protrusions **18** are located between the straight line M**1** connecting the first end of the corner edge **15***a* and the insert center line L to each other and the straight line M**2** connecting the first end of the major cutting edge **15***b* on the side opposite to the first end of the corner edge **15***a* and the insert center line L to each other. The protruding height of the furthest protruding portions **18***a* of the protrusions **18** from the boss surface **12***a* is, for example, in the range of 0.1 mm to about mm as shown in FIG. **8**.

Further, in a diagram B shown with black circles in FIG. **8**, the cross section along the insert center line L at the position of approximately ½ of the length of the wiper edge **15***c* of one cutting edge **15** is similarly set to the position of 0°, and the protruding height of the portion that protrudes furthest from the boss surface **12***a* of a peripheral portion of the cutting edge **15** in the cross section along the insert center line L at each position shifted by 5° each in the counterclockwise direction centered on the insert center line L in FIG. **2** is shown in the range of 120° up to the position of approximately ½ of the length of the wiper edge **15***c* of the other cutting edge **15**. Here, regions indicated by reference signs **15***a* to **15***d* in FIG. **8** are a region of the corner edge **15***a*, a region of the major cutting edge **15***b*, a region of the wiper edge **15***c*, and a region of the minor cutting edge **15***d* of the cutting edge **15**.

Further, in the present embodiment, a protruding ridge portion **19** that protrudes with respect to the boss surface **12***a* (outward from the insert main body in the direction of the insert center line L from the boss surface **12***a*) along the minor cutting edge **15***d* extending to the region of the boss surface **12***a* is formed on an outer peripheral portion of the boss surface **12***a*. Similar to the protrusions **18**, in the cross section orthogonal to the minor cutting edge **15***d* as shown in FIG. **6**, the protruding ridge portion **19** is also formed to rise and protrude from the boss surface **12***a* while drawing a concave curve such as a concave arc which is in contact with the boss surface **12***a* from the inner periphery side of the polygonal surface **12** as it goes toward the outer periphery side of the polygonal surface **12**, to protrude in the direction of the insert center line L while drawing a convex curve such as a convex arc which is in contact with the concave curve on the inner periphery side of the polygonal surface **12** and then retract on the outer periphery side of the polygonal surface **12** in the direction of the insert center line L, and to intersect with the flank face **14** via an inclined face **19***a* in a straight line shape which is inclined to the polygonal surface **12** side opposite to the subject polygonal surface **12**. The minor cutting edge **15***d* extending to the region of the boss surface **12***a* is formed in the intersecting ridgeline between the inclined face **19***a* and the flank face **14**.

The position of the minor cutting edge **15***d* formed at the intersecting ridgeline between the inclined face **19***a* and the flank face **14** in the direction of the insert center line L is equivalent to the positions of the boss surface **12***a* and the wiper edge **15***c* in the direction of the insert center line L. In addition, as shown in the diagram B of FIG. **8**, the protruding ridge portion **19** also extends from the rake face of the portion of the minor cutting edge **15***d* which is continuous with the corner edge **15***a* to the side opposite to the corner edge **15***a* with a predetermined protruding height and a predetermined length, and then extends such that it gradually retracts in the direction of the insert center line L toward the wiper edge **15**c of the other cutting edge **15** which intersects with this minor cutting edge **15**d to lower the protruding height. Here, the protruding height of the furthest protruding portion **19**b of the protruding ridge portion **19** which protrudes furthest from the boss surface **12**a is lower than the protruding height of the furthest protruding portions **18**a of the protrusions **18**.

Here, the cutting insert having the insert main body **11** formed of the hard material such as the cemented carbide is manufactured according to the basic process of powder metallurgy. That is, in a case in which the insert main body **11** is made of the cemented carbide, powder press forming with a mold is performed using a granulated powder containing tungsten carbide powder and cobalt powder as main components, and optionally chromium, tantalum, and the like as sub components. A press formed body thus obtained is sintered for a predetermined time in a sintering furnace controlled to an appropriate atmosphere and temperature, and thus it is possible to manufacture a sintered body to be the insert main body **11**. The basic shape of the insert main body **11** is reflected by the design of the mold, and the detailed shape of the insert main body **11**, that is, the shape of the protrusions **18**, the protruding ridge portion **19**, the inclined portion **12**b, or a gently inclined portion or a steeply inclined portion that will be described later is obtained by mold forming.

The cutting insert of the present embodiment as described above is detachably mounted on the insert mounting seat **22** formed on the outer periphery of the tip end portion of the tool main body **21** of the indexable cutting tool such as an indexable end mill as shown in FIGS. **9** to **16**, and constitutes the indexable cutting tool according to an embodiment of the present invention as shown in FIGS. **17** to **24**. The tool main body **21** has a substantially cylindrical shape centered on an axis O, and at the time of cutting operation, a posterior end portion thereof is gripped by a main shaft of a machine tool and is rotated around the axis O in a tool rotation direction T, so that the cutting insert of the above-described embodiment mounted on the insert mounting seat **22** performs the cutting operation on a work material.

A plurality of (five in the present embodiment) chip pockets **23** are formed on the outer periphery of the tip end portion of the tool main body **21**, and the insert mounting seat **22** is formed in a concave shape on an outer periphery of a tip end portion of a wall face of the insert pocket **23** which faces the tool rotation direction T, and includes a planar bottom surface **22**a that faces the tool rotation direction T side, and a plurality of planar wall surfaces **22**b that are disposed at intervals on the tool rotation direction T side from the bottom surface **22**a and can come into contact with the insert constraining surface **17** of the insert main body **11**.

Further, a screw hole **22**c into which a clamp screw **24** inserted into the mounting hole **16** is screwed is formed in the bottom surface **22**a, and accommodation recesses **22**d for accommodating the protrusions **18** formed on the opening of the attachment hole **16** of the other polygonal surface **12** serving as the seating surface of the insert main body **11** are formed around an opening of the screw hole **22**c. When seen from the tool rotation direction T side, as shown in FIG. **12**, the accommodation recesses **22**d are formed in a shape in which a plurality of (three) crescent-shaped recesses for accommodating the plurality of (three) protrusions **18** are formed around a circular recess centered on the screw hole **22**c at equal intervals in a peripheral direction.

The cutting insert of the above-described embodiment is seated on the insert mounting seat **22** in such a manner that one polygonal surface **12** of the insert main body **11** is caused to serve as the rake face and to face the tool rotation direction T side, the boss surface **12**a of the other polygonal surface **12** is closely attached to the bottom surface **22**a of the insert mounting seat **22**, and the protrusions **18** protruding with respect to the boss surface **12**a are accommodated in the accommodation recesses **22**d. At this time, the corner edge **15**a located at one corner of the one polygonal surface **12** protrudes to the outer periphery side of the tool main body **21**, and the major cutting edge **15**b extending from a first end of the corner edge **15**a faces the tip end side of the tool main body **21**.

Further, in a state in which the cutting insert is seated on the insert mounting seat **22** in this manner, the wiper edge **15**c extending from a first end of the major cutting edge **15**b facing the tip end side of the tool main body **21** is disposed to have a concavity angle of 2° or less with respect to a plane perpendicular to the axis O. That is, the wiper edge **15**c is disposed along the plane perpendicular to the axis O, or is disposed to be inclined such that it goes toward a posterior end side of the tool main body **21** at an angle of 2° or less with respect to this plane as it goes toward the inner periphery side of the tool main body.

The cutting insert seated on the insert mounting seat **22** in this manner is fixed by screwing the clamp screw **24** inserted into the mounting hole **16** of the insert main body **11** into the screw hole **22**c of the bottom surface **22**a of the insert mounting seat **22**. At this time, the insert constraining surface **17** of the side surface **13** that is continuous with the cutting edge **15** not used for cutting in the insert main body **11** is brought into contact with the wall face **22**b of the insert mounting seat **22** to constrain the rotation of the insert main body **11** around the insert center line L.

The indexable cutting tool to which the cutting insert is mounted in this manner is fed in a direction perpendicular to the axis O while being rotated around the axis O during normal cutting, so that the work material is cut exclusively by the corner edge **15**a protruding to the outer periphery side of the tool main body **21**, and the major cutting edge **15**b and the wiper edge **15**c which are continuous with a first end of the corner edge **15**a. Further, in an engraving operation of a pocket by inclination cutting operation, the tool main body **21** is also fed to the tip end side in the axis O direction, and cutting is also performed by the minor cutting edge **15**d intersecting with the wiper edge **15**c.

Here, the major cutting edge **15**b has a straight line shape or a convex curve shape having a larger radius of curvature than the corner edge **15**a, and the wiper edge **15**c also has a straight line shape or a convex curve shape having a larger radius of curvature than the convex curve formed by the major cutting edge **15**b, so that the thickness of a chip generated by an inner periphery side portion of the tool main body **21** is thin, and it is possible to suppress an increase in cutting resistance even when the tool main body **21** is fed at a high feed amount.

Further, in the cutting insert and the indexable cutting tool having the above-described configuration, a plurality of protrusions **18** protruding with respect to the boss surface **12**a formed on the polygonal surface **12** around the opening of the mounting hole **16** are formed on the opening of the mounting hole **16** in the two polygonal surfaces **12** of the insert main body **11** at intervals in the peripheral direction in the inner periphery side region of the major cutting edge **15**b. Therefore, the chip that is generated by the major cutting edge **15**b facing the tip end side of the tool main body

21 and flows out to the inner periphery side of the polygonal surface **12** is brought into sliding contact with the protrusions **18** located in the inner periphery side region of the major cutting edge **15***b*, and thus it is possible to give resistance to the chip and to control its outflow direction.

For example, since the protrusions **18** are formed at intervals in the peripheral direction, the chip which is brought into sliding contact with the protrusion **18** in the inner periphery side region of the major cutting edge **15***b* facing the tip end side of the tool main body **21** and to which resistance is given is guided to a portion between the protrusions **18** adjacent to the subject protrusion **18** in the counterclockwise direction in FIG. **2** and is curled, and thus it is possible to control the outflow direction such that the chip does not flow the minor cutting edge **15***d* extending to the posterior end side of the tool main body **21** from the corner edge **15***a* protruding to the outer periphery side of the tool main body **21** and to process the chip. Therefore, when the engraving operation of the pocket is performed, it is possible to prevent the chip from being caught between the minor cutting edge **15***d* extending from the corner edge **15***a* to the posterior end side of the tool main body **21** and an inner wall surface of the pocket and a fracture from being generated in the minor cutting edge **15***d*.

On the other hand, since the plurality of protrusions **18** are formed on the opening of the mounting hole **16** at intervals in the peripheral direction, the boss surface **12***a* of the polygonal surface **12** can be formed to reach the opening of the mounting hole **16** in a portion between the intervals, and the bottom surface **22***a* of the insert mounting seat **22** can also be formed up to a position close to the opening of the screw hole **22***c*. Therefore, even if the protrusions **18** are formed, it is possible to prevent an area of close attachment between the boss surface **12***a* of the insert main body **11** and the bottom surface **22***a* of the insert mounting seat **22** from becoming too small as compared with a case in which the protrusions **18** are formed over the entire periphery of the opening of the mounting hole **16**. Further, if the protrusions **18** are formed over the entire periphery of the opening of the mounting hole **16** as described above, the chip may remain in contact with the protrusions **18** to cause an increase in cutting resistance, however in the cutting insert having the above-described configuration, the protrusions are formed at intervals in the peripheral direction, and thus there is no possibility of causing such an increase in cutting resistance.

Moreover, the protrusions **18** are formed on the opening of the mounting hole **16** on the innermost periphery side of the boss surface **12***a*, and in the outer periphery side of the boss surface **12***a*, it is possible to secure the area of close attachment with the bottom surface **22***a* of the insert mounting seat **22** which is the same as the related art. Therefore, it is possible to prevent mounting stability of the cutting insert from being impaired, the insert main body **11** can be reliably held by the insert mounting seat **22**, and stable cutting can be performed over a long period of time.

Further, in the cutting insert of the present embodiment, the furthest protruding portions **18***a* of the protrusions **18** which protrude furthest from the boss surface **12***a* extend with a predetermined protruding height and a predetermined length around the opening of the mounting hole **16**. Therefore, not only when a chip having a wide width is generated but also when a chip having a narrow width is generated by the major cutting edge **15***b*, it is possible to reliably bring the chip into sliding contact with the protrusions **18** and to control the outflow direction, and it is also possible to prevent wear of the protrusions **18** due to the sliding contact of the chip and to achieve stable chip processing over a long period of time. A height difference in the direction of the insert center line L between the furthest protruding portions **18***a* of the protrusions **18** and a position of the cutting edge **15** which protrudes furthest in the direction of the insert center line L (in the present embodiment, a first end of the corner edge **15***a*) is preferably in the range of 0.4 mm to 1.0 mm. If the height difference is less than 0.4 mm, it may not be possible to effectively control the flow and a discharging property of the chip, while it becomes difficult to manufacture an insert main body with a height difference of more than 1.0 mm.

Further, in the present embodiment, when seen in the direction facing the polygonal surface **12** of the insert main body **11**, as shown in FIGS. **2** and **8**, the furthest protruding portions **18***a* are located between the straight line **M1** connecting the first end of the corner edge **15***a* and the insert center line L to each other and the straight line **M2** connecting the first end of the major cutting edge **15***b* on the side opposite to the first end of the corner edge **15***a* and the insert center line L to each other. Therefore, when high feeding processing or high cutting operation is performed, the chip which is generated by the major cutting edge **15***b* and flows out to the inner periphery side of the polygonal surface by making the polygonal surface **12** serving as the rake face straddle the straight lines **M1** and **M2** can be more reliably brought into sliding contact with the furthest protruding portions **18***a* of the protrusions **18**. Further, by bringing the chip into sliding contact with the furthest protruding portions **18***a* in this manner, it is possible to prevent the chip from coming into sliding contact with the clamp screw **24**, so that it is possible to prevent wear of the clamp screw **24** and the mounting stability of the cutting insert can be further improved.

Here, in a case in which the insert main body **11** has a triangular plate shape in which the two polygonal surfaces **12** each have three corners as in the present embodiment, the furthest protruding portions **18***a* of the protrusions **18** are preferably located in an angle range of 15° to 40° centered on the insert center line L from the straight line **M2** connecting a first end of the major cutting edge **15***b* on the side opposite to a first end of the corner edge **15***a* and the insert center line L to each other toward the corner edge **15***a* side with which the major cutting edge **15***b* is continuous, between the straight lines **M1** and **M2**, when seen in the direction facing the polygonal surface **12**.

That is, in a case in which the insert main body **11** having the triangular plate shape is mounted on the tool main body **21**, such an angle range is a portion which is located on the inner periphery side of the tool main body **21** in the major cutting edge **15***b* and at which a thin chip is generated, and the furthest protruding portions **18***a* of the protrusions **18** are disposed in the inner periphery side region of the major cutting edge **15***b* in such a portion, and thus the outflow direction of the entire chip can be effectively controlled and the cutting resistance can be further reduced. Further, it is also possible to prevent premature wear of the protrusions **18** due to a thick chip scraping the furthest protruding portions **18***a* of the protrusions **18**.

On the other hand, in the cutting insert of the present embodiment, the cutting edge **15** further includes a minor cutting edge **15***d* extending from the second end of the corner edge **15***a* to the other cutting edge **15** adjacent to the second end side of the corner edge **15***a*. In a case in which the engraving operation of the pocket is performed on a work material such as a mold by the inclination cutting operation, the minor cutting edge **15***d* which is located on the inner periphery side of the major cutting edge **15***b* facing the tip end side of the tool main body **21** as described above is also used for cutting. This minor cutting edge **15***d* extends to the region of the boss surface **12***a* on the side opposite to the corner edge **15***a*, and in the portion extending to the region of the boss surface **12***a*, the minor cutting edge is formed on the intersecting ridgeline between the inclined face **19***a* that goes toward the polygonal surface **12** side opposite to the subject polygonal surface **12** as it goes toward the outer periphery side of the subject polygonal surface **12** and the flank face **14**.

Therefore, at the portion of the minor cutting edge **15***d* which extends to the region of the boss surface **12***a*, it is possible to increase an edge angle of the minor cutting edge **15***d* and to improve a cutting edge strength. Thus, when the engraving operation of the pocket is performed on the work material as described above, for example, in a state in which the outflow direction of the chip cannot be sufficiently controlled by the protrusions **18**, even if the chip flows from the corner edge **15***a* facing the outer periphery side of the tool main body **21** toward the minor cutting edge **15***d* side extending to the posterior end side of the tool main body and is caught between the inner wall surface of the pocket and the minor cutting edge **15***d*, it is possible to prevent the fracture from being generated in the minor cutting edge **15***d*. Therefore, according to the present embodiment, in a case in which the insert main body **11** is rotated and reattached and the engraving operation is performed using the new cutting edge **15**, it is possible to prevent a situation in which the minor cutting edge **15***d* of the new cutting edge **15** becomes unusable due to the fracture, and it is possible to reliably use the plurality of cutting edge **15** formed on the insert main body **11**.

Further, in the present embodiment, to form the minor cutting edge **15***d* extending to the region of the boss surface **12***a* on the intersecting ridgeline between the inclined face **19***a* and the flank face **14** in this manner, the protruding ridge portion **19** that protrudes with respect to the boss surface **12***a* is formed on the outer peripheral portion of the polygonal surface **12** along the minor cutting edge **15***d* of a portion extending to the region of the boss surface **12***a*, and the inclined face **19***a* is formed on an outer peripheral surface of the protruding ridge portion **19** facing the outer periphery side of the polygonal surface **12**. For this reason, even if the chip flows toward the minor cutting edge **15***d* side during the engraving operation as described above, before the chip is caught between the minor cutting edge **15***d* and the inner wall surface of the pocket, the chip is brought into sliding contact with an inner peripheral surface of the protruding ridge portion **19** that protrudes from the boss surface **12***a*, which faces the inner periphery side and receives resistance, and thus the chip is curled and processed. Therefore, it is possible to prevent the chip from being caught.

In the present embodiment, to form a portion of the minor cutting edge **15***d* which extends to the region of the boss surface **12***a* on the intersecting ridgeline between the inclined face **19***a* and the flank face **14** in this manner, the protruding ridge portion **19** that protrudes with respect to the boss surface **12***a* is formed on the outer peripheral portion of the polygonal surface **12** along the minor cutting edge **15***d* of a portion extending to the region of the boss surface **12***a*, and the outer peripheral surface of the protruding ridge portion **19** is formed as the inclined face **19***a*, but, without forming such a protruding ridge portion **19**, as in a second embodiment of the cutting insert of the present invention shown in FIGS. **25** to **31**, the chamfered inclined face **19***a* that is inclined toward the opposite polygonal surface **12** side without protruding with respect to the boss surface **12***a* as it goes toward the outer periphery side may be formed in the outer peripheral portion of the polygonal surface **12** in the region of the boss surface **12***a*, and a portion of the minor cutting edge **15***d* which extends to the region of the boss surface **12***a* may be formed on the intersecting ridgeline between the inclined face **19***a* and the flank face **14**.

Even if the chamfered inclined face **19***a* is formed and the minor cutting edge **15***d* is formed on the intersecting ridgeline between the flank face **14** and the chamfered inclined face **19***a* in this manner, a large edge angle of the minor cutting edge **15***d* in the region of the boss surface **12***a* can be ensured and the cutting edge strength can be improved, and thus it is possible to prevent the fracture from being generated in the minor cutting edge **15***d* even if the chip is caught between the inner wall surface of the pocket and the minor cutting edge **15***d*. In the second embodiment shown in FIGS. **25** to **31** and third and fourth embodiments that will be described later, the same parts as those of the first embodiment are designated by the same reference signs and a description thereof will be omitted.

In the first embodiment, the boss surface **12***a* is perpendicular to the insert center line L, whereas the inclined portion **12***b* that is inclined to protrude in the direction of the insert center line Las it goes toward the cutting edge **15** side is formed in the outer peripheral portion of the polygonal surface **12**, and the corner edge **15***a*, the major cutting edge **15***b*, and the portion of the minor cutting edge **15***d* which is in contact with the corner edge **15***a* are formed on the intersecting ridgeline between the inclined portion **12***b* and the flank face **14**. Therefore, it is possible to increase a rake angle of each of the corner edge **15***a* and the major cutting edge **15***b* to a regular angle side to ensure sharp cutting quality, and it is possible to reduce the cutting resistance at the time of the high feeding processing or the high cutting operation.

In the first embodiment, the inclined portion **12***b* is inclined to protrude in the direction of the insert center line L at a predetermined inclination as it goes from the boss surface **12***a* toward the cutting edge **15** side except that it has a positive land on the cutting edge **15** side. However, as in a third embodiment of the cutting insert of the present invention shown in FIGS. **32** to **38**, particularly in FIG. **38**, in a cross section orthogonal to the major cutting edge **15***b*, the inclined portion **12***b* may have a first steeply inclined portion **20***a* that protrudes in the direction of the insert center line L as it goes from the boss surface **12***a* toward the major cutting edge **15***b* side, a gently inclined portion **20***b* that is continuous with the first steeply inclined portion **20***a* on the major cutting edge **15***b* side and protrudes in the direction of the insert center line L at a gradient gentler than the first steeply inclined portion **20***a* as it goes toward the major cutting edge **15***b* side, and a second steeply inclined portion **20***c* that is continuous with the gently inclined portion **20***b* on the major cutting edge **15***b* side and protrudes in the direction of the insert center line L at a gradient steeper than the gently inclined portion as it goes toward the major cutting edge **15***b* side.

By providing the first and second steeply inclined portions **20***a* and **20***c* and the gently inclined portion **20***b* as described above, when the chip flows from the second steeply inclined portion **20***c* to the gently inclined portion **20***b*, or when the chip flows from the gently inclined portion **20***b* to the first steeply inclined portion **20***a*, it is possible to give resistance to the chip, and, particularly in the high feeding processing, even in a case in which a distance from the cutting edge **15** to the boss surface **12***a* or a height difference therebetween in the direction of the insert center line L is large, it is possible to improve a processing property of the chip. Preferably, connecting portions between the first and second steeply inclined portions **20***a* and **20***c* and the gently inclined portion **20***b* are smoothly connected in a concave-convex curved shape in a cross section orthogonal to the major cutting edge **15***b* as shown in FIG. **38**. Preferably, the first and second steeply inclined portions **20***a* and **20***c* and the gently inclined portion **20***b* are substantially similar in a cross section orthogonal to the cutting edge **15** over the entire length of the cutting edge **15** formed on the inclined portion **12***b*.

Nest, FIGS. **39** to **45** show a fourth embodiment of a cutting insert of the present invention. The fourth embodiment has a first region in which a rake angle in the cross section along the insert center line L gradually increases as it goes from the end portion of the major cutting edge **15***b* on the side opposite to the corner edge **15***a* toward the corner edge **15***a* side, a second region in which the rake angle gradually decreases as it goes from the first region toward the corner edge **15***a* side, and a third region in which the rake angle gradually increases in the range smaller than the first region as it goes from the second region toward the minor cutting edge **15***d* side in a portion including at least a part of the corner edge **15***a* and the minor cutting edge **15***d*, and the rake angle in the third region is in the range of 15° to 18°.

Further, the cutting edge **15** may have a fourth region in which the rake angle gradually decreases at a rate of change larger than in the first to third regions as it goes from the third region toward the end portion of the minor cutting edge **15***d* on a side opposite to the corner edge **15***a*. Further, the rake angle in the second region may be in the range of 15° to 25°. Furthermore, in a case in which the insert main body **11** has a triangular plate shape in which the two polygonal surfaces **12** each have three corners, the position where the rake angle is maximum at a boundary between the first region and the second region may be in the angle range of 15° to 45° from a straight line passing through the end portion of the major cutting edge **15***b* on the side opposite to the corner edge **15***a* and the insert center line L toward the corner edge **15***a* side centered on the insert center line L, when seen in the direction facing the polygonal surface **12** along the insert center line L.

In the cutting insert of the fourth embodiment as described above, particularly in the high cutting operation, a portion from the end portion of one major cutting edge **15***b* facing the tip end side of the tool main body **21** on the side opposite to the corner edge **15***a* to the corner edge **15***a* facing the outer periphery side of the tool main body **21** and a portion of the minor cutting edge **15***d* extending from the second end of the corner edge **15***a* on the corner edge **15***a* side are exclusively used for cutting.

Here, in the portion of the tool main body **21** on the inner periphery side which goes from the end portion of the major cutting edge **15***b* on the side opposite to the corner edge **15***a* toward the corner edge **15***a* side, a relatively thin chip is generated, but in the cutting insert of the fourth embodiment, this portion is the first region in which the rake angle in the cross section along the insert center line L gradually increases, the outflow direction can be controlled to guide the entire chip that is generated in a wide width by giving sharp cutting quality to the major cutting edge **15***b* to the inner periphery side (the axis O side) of the tool main body **21**, that is, to guide the chip to the protrusions **18** side while the cutting edge strength with respect to the thin chip is ensured, and the processing property of the chip can be improved.

Further, the portion that goes from the first region toward the major cutting edge **15***b* on the corner edge **15***a* side is the second region in which the rake angle gradually decreases, and it is possible to secure the cutting edge strength and to prevent the fracture or the like against a case in which the thickness of the chip gradually increases as it goes toward the outer periphery side of the tool main body **21** and cutting load or stress increases.

Further, the portion including at least a part of the corner edge **15***a* and the minor cutting edge **15***d* from the second region is the third region in which the rake angle gradually increases in the range smaller than that in the first region as it goes toward the minor cutting edge side. Therefore, in the third region which is located on the outermost periphery of the tool main body **21**, the rake angle gradually increases as it goes toward the minor cutting edge **15***d* side while maintaining the cutting edge strength by the rake angle reduced passing through the second region, and thus the chip can be wound into the inner periphery side of the tool main body **21** with a small curl diameter, it is possible to prevent the chip from being caught in combination with the improvement of the chip discharging property by the first region, and a preferable machined face quality can be obtained. Since the rake angle of the cutting edge **15** in the third region is in the range of 15° to 18°, it is possible to more reliably secure the cutting edge strength and to prevent the chip from being caught.

INDUSTRIAL APPLICABILITY

The fracture of the cutting edge due to the chip being caught can be prevented without impairing the mounting stability of the cutting insert on the insert mounting seat even if the high feeding processing, the high cutting operation, or the engraving operation of the pocket is performed, and stable cutting can be performed over a long period of time.

REFERENCE SIGNS LIST

11 Insert main body
12 Polygonal surface
12*a* Boss surface
12*b* Inclined portion
13 Side surface
14 Flank face
15 Cutting edge
15*a* Corner edge
15*b* Major cutting edge
15*c* Wiper edge
15*d* Minor cutting edge
16 Mounting hole
17 Insert constraining surface
18 Protrusion
18*a* Furthest protruding portion of protrusion **18**
19 Protruding ridge portion
19*a* Inclined face
19*b* Furthest protruding portion of protruding ridge portion **19**
20*a* First steeply inclined portion
20*b* Gently inclined portion
20*c* Second steeply inclined portion
21 Tool main body
22 Insert mounting seat
22*a* Bottom surface of insert mounting seat **22**
22*b* Wall face of insert mounting seat **22**
22*c* Screw hole
22*d* Accommodation recess

23 Chip pocket
24 Clamp screw
L Insert center line
O Axis of tool main body **21**
T Tool rotation direction

What is claimed is:

1. A cutting insert comprising:

a polygonal plate-shaped insert main body that includes: two polygonal surfaces which have a polygonal shape and of which one serves as a rake face and the other serves as a seating surface; a side surface which is arranged around the two polygonal surfaces and in which a flank face intersecting with the rake face of the polygonal surfaces is formed; and a cutting edge which is formed on an intersecting ridgeline between the rake face and the flank face,

wherein the insert main body has a mounting hole that penetrates the insert main body centered on an insert center line passing through centers of the two polygonal surfaces, has a rotationally symmetrical shape with respect to the insert center line, and has a front-back inversion symmetrical shape with respect to the two polygonal surfaces,

wherein the cutting edge includes at least a corner edge located at a corner of the polygonal surface and a major cutting edge extending from a first end of the corner edge,

wherein, in an opening of the mounting hole in the two polygonal surfaces, a plurality of protrusions protruding with respect to a boss surface formed around the opening of the mounting hole are formed at intervals in a peripheral direction in an inner periphery side region of the major cutting edge, and

wherein, in the protrusions, when seen in a direction facing the polygonal surface, furthest protruding portions which protrude furthest from the boss surface are located between a straight line connecting the first end of the corner edge and the insert center line to each other and a straight line connecting a first end of the major cutting edge on a side opposite to the first end of the corner edge and the insert center line to each other,

in the protrusions, the furthest protruding portions which protrude furthest from the boss surface extend with a predetermined length around the opening of the mounting hole,

the insert main body has a triangular plate shape in which each of the two polygonal surfaces has three corners, and

when seen in the direction facing the polygonal surface, the furthest protruding portions are located in an angle range of 15° to 40° centered on the insert center line from the straight line connecting the first end of the major cutting edge on the side opposite to the first end of the corner edge and the insert center line to each other toward the corner edge side, and

each of the furthest protruding portions is located offset from the corner edge in a peripheral direction of the insert.

2. The cutting insert according to claim **1**,

wherein the cutting edge further includes a minor cutting edge extending from a second end of the corner edge toward the other cutting edge adjacent to a second end side of the corner edge, and

wherein the minor cutting edge extends to a region of the boss surface at least on a side opposite to the corner edge, and in a portion extending to the region of the boss surface, the minor cutting edge is formed on an intersecting ridgeline between an inclined face that goes toward the polygonal surface side opposite to the subject polygonal surface as the inclined face goes toward an outer periphery side of the subject polygonal surface and the flank face.

3. The cutting insert according to claim **2**,

wherein, in an outer peripheral portion of the polygonal surface, a protruding ridge portion that protrudes with respect to the boss surface is formed along the minor cutting edge of the portion extending to the region of the boss surface, and

wherein the inclined face is formed on an outer peripheral surface of the protruding ridge portion facing the outer periphery side of the polygonal surface.

4. An indexable cutting tool in which the cutting insert according to claim **3** is detachably mounted on an insert mounting seat formed on an outer periphery of a tip end portion of a tool main body which is rotated around an axis in such a manner that a clamp screw which is inserted into the mounting hole is screwed into a screw hole formed in a bottom surface of the insert mounting seat which faces in a tool rotation direction,

wherein, in the insert main body, one polygonal surface of the two polygonal surfaces is caused to serve as a rake face and to face in the tool rotation direction, and the boss surface of the other polygonal surface is closely attached to the bottom surface of the insert mounting seat,

wherein the insert main body is mounted in such a manner that the one corner edge of the one polygonal surface is caused to face an outer periphery side of the tool main body and the one major cutting edge extending from a first end of the one corner edge is caused to face a tip end side of the tool main body, and

wherein, in the bottom surface of the insert mounting seat, accommodation recesses for accommodating the protrusions of the other polygonal surface are formed around an opening of the screw hole.

5. An indexable cutting tool in which the cutting insert according to claim **2** is detachably mounted on an insert mounting seat formed on an outer periphery of a tip end portion of a tool main body which is rotated around an axis in such a manner that a clamp screw which is inserted into the mounting hole is screwed into a screw hole formed in a bottom surface of the insert mounting seat which faces in a tool rotation direction,

wherein, in the insert main body, one polygonal surface of the two polygonal surfaces is caused to serve as a rake face and to face in the tool rotation direction, and the boss surface of the other polygonal surface is closely attached to the bottom surface of the insert mounting seat,

wherein the insert main body is mounted in such a manner that the one corner edge of the one polygonal surface is caused to face an outer periphery side of the tool main body and the one major cutting edge extending from a first end of the one corner edge is caused to face a tip end side of the tool main body, and

wherein, in the bottom surface of the insert mounting seat, accommodation recesses for accommodating the protrusions of the other polygonal surface are formed around an opening of the screw hole.

6. The cutting insert according to claim **1**,

wherein the boss surface is a plane perpendicular to the insert center line, and

wherein an inclined portion that is inclined to protrude in a direction of the insert center line as the inclined portion goes from the boss surface toward the cutting edge side is formed on the polygonal surface.

7. The cutting insert according to claim **6**, wherein, in a cross section orthogonal to the major cutting edge, the inclined portion has: a first steeply inclined portion that protrudes in the direction of the insert center line as the first steeply inclined portion goes from the boss surface toward the major cutting edge side; a gently inclined portion that is continuous with the first steeply inclined portion on the major cutting edge side and protrudes in the direction of the insert center line at a gradient gentler than the first steeply inclined portion as the gently inclined portion goes toward the major cutting edge side; and a second steeply inclined portion that is continuous with the gently inclined portion on the major cutting edge side and protrudes in the direction of the insert center line at a gradient steeper than the gently inclined portion as the second steeply inclined portion goes toward the major cutting edge side.

8. An indexable cutting tool in which the cutting insert according to claim **7** is detachably mounted on an insert mounting seat formed on an outer periphery of a tip end portion of a tool main body which is rotated around an axis in such a manner that a clamp screw which is inserted into the mounting hole is screwed into a screw hole formed in a bottom surface of the insert mounting seat which faces in a tool rotation direction,

wherein, in the insert main body, one polygonal surface of the two polygonal surfaces is caused to serve as a rake face and to face in the tool rotation direction, and the boss surface of the other polygonal surface is closely attached to the bottom surface of the insert mounting seat,

wherein the insert main body is mounted in such a manner that the one corner edge of the one polygonal surface is caused to face an outer periphery side of the tool main body and the one major cutting edge extending from a first end of the one corner edge is caused to face a tip end side of the tool main body, and

wherein, in the bottom surface of the insert mounting seat, accommodation recesses for accommodating the protrusions of the other polygonal surface are formed around an opening of the screw hole.

9. An indexable cutting tool in which the cutting insert according to claim **4** is detachably mounted on an insert mounting seat formed on an outer periphery of a tip end portion of a tool main body which is rotated around an axis in such a manner that a clamp screw which is inserted into the mounting hole is screwed into a screw hole formed in a bottom surface of the insert mounting seat which faces in a tool rotation direction,

wherein, in the insert main body, one polygonal surface of the two polygonal surfaces is caused to serve as a rake face and to face in the tool rotation direction, and the boss surface of the other polygonal surface is closely attached to the bottom surface of the insert mounting seat,

wherein the insert main body is mounted in such a manner that the one corner edge of the one polygonal surface is caused to face an outer periphery side of the tool main body and the one major cutting edge extending from a first end of the one corner edge is caused to face a tip end side of the tool main body, and

wherein, in the bottom surface of the insert mounting seat, accommodation recesses for accommodating the protrusions of the other polygonal surface are formed around an opening of the screw hole.

10. An indexable cutting tool in which the cutting insert according to claim **1** is detachably mounted on an insert mounting seat formed on an outer periphery of a tip end portion of a tool main body which is rotated around an axis in such a manner that a clamp screw which is inserted into the mounting hole is screwed into a screw hole formed in a bottom surface of the insert mounting seat which faces in a tool rotation direction,

wherein, in the insert main body, one polygonal surface of the two polygonal surfaces is caused to serve as a rake face and to face in the tool rotation direction, and the boss surface of the other polygonal surface is closely attached to the bottom surface of the insert mounting seat,

wherein the insert main body is mounted in such a manner that the one corner edge of the one polygonal surface is caused to face an outer periphery side of the tool main body and the one major cutting edge extending from a first end of the one corner edge is caused to face a tip end side of the tool main body, and

wherein, in the bottom surface of the insert mounting seat, accommodation recesses for accommodating the protrusions of the other polygonal surface are formed around an opening of the screw hole.

11. The cutting insert according to claim **1**, wherein protruding heights the furthest protruding portions from the boss surface is in a range of 0.1 mm to 0.15 mm.

12. The cutting insert according to claim **1**,

wherein, in an outer peripheral portion of the polygonal surface, a protruding ridge portion that protrudes with respect to the boss surface is formed along the minor cutting edge of the portion extending to the region of the boss surface,

the inclined face is formed on an outer peripheral surface of the protruding ridge portion facing the outer periphery side of the polygonal surface,

the boss surface is a plane perpendicular to the insert center line,

an inclined portion that is inclined to protrude in a direction of the insert center line as the inclined portion goes from the boss surface toward the cutting edge side is formed on the polygonal surface, and

the protruding ridge portion and the inclined portion are formed in an inside part of an outer periphery part of the insert alternately.

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